1993 Study of Travel Speed and Delay in the MAG Region

Final Report

prepared for

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EXECUTIVE SUMMARY

The accuracy of speed data has become important to the annual process of evaluating the conformity of transportation plans to state and federal air quality implementation plans. Because of this, the Maricopa Association of Governments Transportation Planning Office (MAGTPO) sponsored the 1993 Study of Travel Speed and Delay in the MAG Region to obtain field measured travel speeds and delays for incorporation into the regional transportation model. The primary purpose of the study was the collection and analysis of travel speed data. A secondary purpose of the study was the collection of intersection stopped delay data at signalized intersections for a future submodel of the regional transportation model.

The results of the 1993Travel Speed Study were compared to results of similar previous studies which were conducted in 1957, 1962, 1966, 1970, 1976, 1979 and most recently in 1986. Comparison of the various studies provides a historical perspective on travel speed trends.

The majority of the travel time and speed data for the 1993 Study were collected in from mid-October to mid-December, 1993 with data recollect occurring primarily in late-January, and mid-March to mid-April, 1994. The data were collected on Monday through Friday for the following three time periods:

- morning period: 7:00 a.m. to 9:00 a.m,
- midday period: 10:00 a.m. to 2:00 p.m.,
- evening period: 4:00 p.m. to 6:00 p.m.

Travel time and speed data were collected for more than 800 miles of major streets and 100 miles of freeways and high occupancy vehicle (HOV) lanes for the 1993 Travel Speed Study. The data were collected using the floating car technique which is consistent with the 1986 study. However, data for the 1993 study were collected using a different technology than previous travel speed studies. For the 1993 study, data were collected using Global Positioning (GPS) Unites and portable computers to record speed data and event data, respectively. Using these technologies resulted in the need for only one person per test vehicle instead of two data collectors which were required in the past. Reduction and analysis of the data were achieved through a carefully designed data analysis procedure which took full advantage of an integrated Geographic Information System (GIS), database and statistical analysis software system.

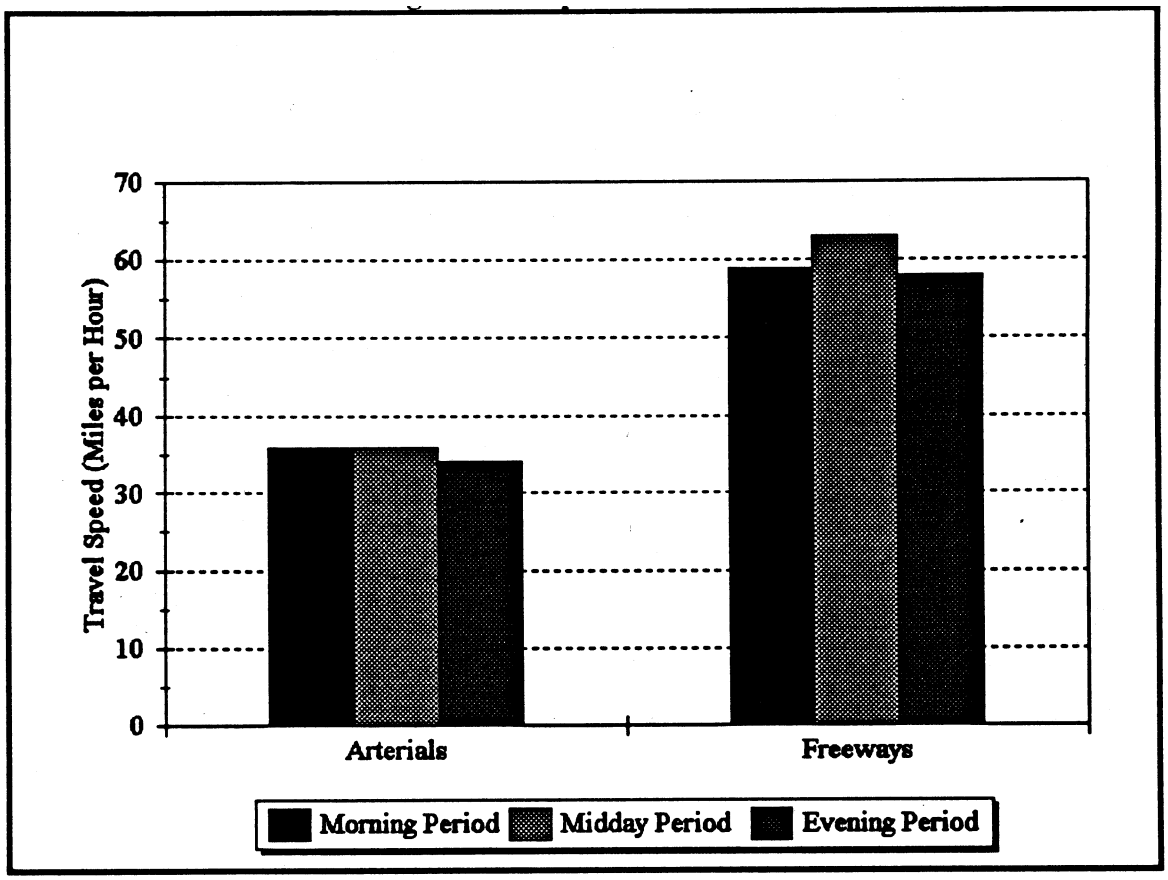
Total travel time delay measurements were also collected at 15 intersections as part of the 1993 Travel Speed Study. The intersections were selected based on MAG area type, left turn phasing, and the roadway classification. Delay data were collected at 12 of the intersections during the evening peak traffic period (4:30 p.m.-5:30 p.m.) and at 3 of the intersections during the morning peak traffic period (7:30 a.m.-8:30 a.m.). Data were collected using camcorders and portable computers. Once the data were collected, they were downloaded and transcribed and input into a statistical analysis program for data reduction. Delay data were collected and analyzed for left turn approaching vehicles and through-right turn approaching vehicles.

The results of the 1993 travel speed and signalized intersection stopped delay data are summarized below. The results are followed by a comparison of the 1993 travel speed data with historic travel speed data.

1993 Study Results

- As illustrated in Figure ES-1, the average travel speeds for all arterials included in the study area are 36 miles per hour during the morning and midday periods, and 34 miles per hour during the evening period. The average travel speeds for all freeways and HOV lanes included in the study are 59 miles per hour during the morning period, 63 miles per hour during the midday period, and 58 miles per hour during the evening period.

Figure ES-1
Average Travel Speeds in 1993



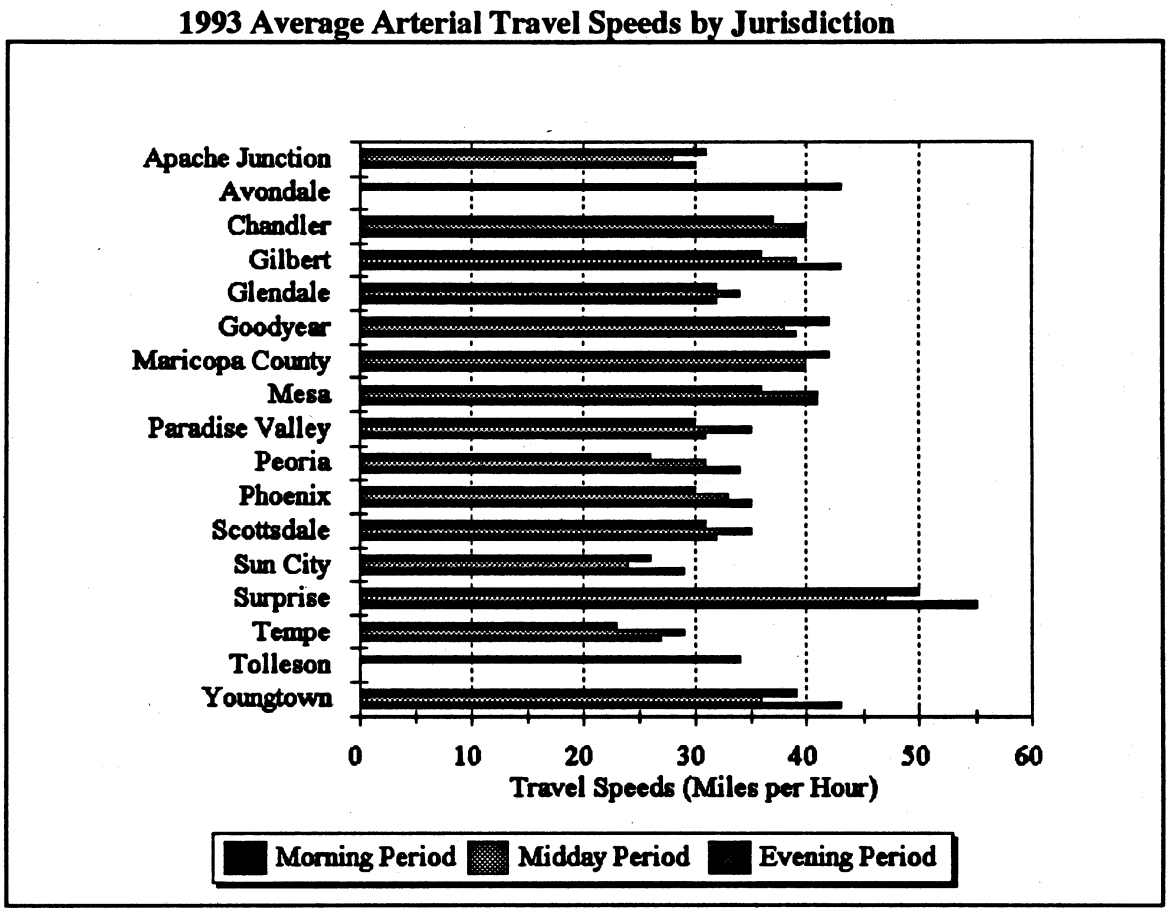
Average Travel Speeds in 1993

- The average freeway travel speed (excluding HOV lanes) during the morning, midday, and evening peak periods is 57, 61, and 54 miles per hour respectively. The average travel speed on an HOV lane during the morning period is 64 miles per hour and 62 miles per hour during the evening period. HOV lanes were not included in the midday sample.
- The average travel speed on principal and minor arterials remain fairly constant through the day. The average travel speeds for principal arterials during the morning, midday, and

evening periods are 32, 33, and 30 miles per hour, respectively. The average travel speeds for minor arterials during the morning, midday, and evening periods are 33, 34, and 32 miles per hour, respectively.

- The lowest average travel speeds for all arterials occur in the most densely developed areas such as the City of Phoenix Central Business District during all time periods analyzed. The average travel speeds in these areas were 29, 28, and 25 miles per hour during the morning, midday and evening periods, respectively. The highest average travel speeds for all arterials occur in the less developed areas such as unincorporated areas with speeds of 43, 42, and 38 miles per hour during the morning, midday and evening periods respectively.
- As shown in Figure ES-2, the slowest arterial travel speeds were observed in the City of Tempe during the morning and evening periods and in the Sun City during the midday period. The fastest arterial speeds were observed in the City of Surprise during all periods, with travel speeds greater than 45 miles per hour during all periods.

Figure ES-2
1993 Average Arterial Travel Speeds by Jurisdiction



- The highest freeway speeds were observed in the City of Chandler during the morning period and the unincorporated areas, which are identified as Maricopa County, during the midday

the unincorporated areas, which are identified as Maricopa County, during the midday and evening periods.

- Travel times between the downtown areas of 9 communities and Sky Harbor International Airport were determined using GIS. The paths of minimum travel time between the downtown areas and Sky Harbor International Airport were determined by GIS using the travel speed data and link length to determine the travel time. In general, it was found that there is not a significant difference in the travel time depending on the direction of travel between two cities. For example, the travel time from Tempe to Phoenix during the morning period is 15.8 minutes, while the trip from Phoenix to Tempe is 15.6 minutes.

- The majority of roadway segments surveyed experience less than one-half minute of stop delay. During the morning and midday periods, less than 8 percent of the roadways surveyed incur stopped delays greater than 30 seconds. During the evening period, less than 24 percent of the roadways surveyed incur stopped delays greater than 30 seconds.

- The majority of the delays encountered in the travel speed runs were recurring in nature. During all periods, the average non recurring delay for any facility type was nearly 0 seconds per mile.

- The mean total travel delay observed at the 15 signalized intersections where total travel delay data were collected ranged from 6.5 seconds to 217.7 seconds for the through-right lanes. The mean total travel delay for left turn lanes ranged from 6.2 seconds to 248.6 seconds.

Historical Speed Changes

A comparison was made between travel speed data collected in the 1993 Study with the data collected in previous studies based on two roadway networks. The first comparison was conducted for those roadway segments included in the roadway network for the 1979 study; the second for the common roadway segments between the 1993 and the 1986 studies. The key findings of the comparison are summarized below.

- The average intercity travel speeds for five major Cities are shown in the Table ES-1 for the years between 1966 and 1993. The results show that overall, there has been an increase in the travel speeds from the various jurisdictions since 1986. Only the route between Glendale and Scottsdale shows a decrease in travel speed in 1993 over 1986.

- There is no definable pattern of increase or decrease of travel speed based upon the results of a comparison on individual roadway segments which were included in both the 1993 and the 1986 travel speed studies.

Table ES-1
Average Late Afternoon Period/Peak Direction Speed
Between Central Business Districts, 1966 to 1993*

	Speeds in Miles Per Hour						Change in Speeds	
	1966	1970	1976	1979	1986	1993	1966 to 1993	1986 to 1993
Glendale-Scottsdale	33.4	31.6	29.6	26.5	26.8	25.1	-8.3	-1.7
Phoenix-Glendale	24.0	26.2	23.0	23.4	22.6	24.6	-6	2.0
Phoenix-Scottsdale	25.3	27.1	22.1	26.5	22.8	28.4	3.1	5.6
Phoenix-Tempe	25.8	28.4	25.1	28.3	24.4	32.7	6.9	8.3
Tempe-Scottsdale	28.5	24.2	25.0	23.9	17.0	20.6	-7.9	3.6
Tempe-Mesa	32.0	30.7	25.7	25.0	19.6	29.3	-2.7	9.7

Speeds for 1966, 1970, 1976, 1979 and 1986 are from the 1986 Phoenix Urbanized Area Travel Speed Study

I. INTRODUCTION

The accuracy of speed data has become important to the annual process of evaluating the conformity of transportation plans to state and federal air quality implementation plans. In October 1992, the Federal Highway Administration (FHWA) and the Environmental Protection Agency (EPA) informed the Arizona Department of Transportation (ADOT) of the need to:

> "...incorporate speeds into the regional transportation model that reflect actual speed data.
>
> ...feedback congested speeds in the model to more accurately reflect the effect of congestion on trips."

Based on this need, the Maricopa Association of Governments Transportation Planning Office (MAGTPO) contracted with Lee Engineering in October 1993 to measure travel speed and delay in the MAG region.

The primary purpose of the 1993 study is to directly address the first issue with the collection of updated travel speed data. MAG is addressing the second issue with an ongoing effort to improve the MAG travel demand models. Part of this improvement will include a future submodel of stopped delay at signalized intersections. The secondary purpose of the 1993 study was to collect signalized intersection stopped delay for calibration of this submodel.

This study is also a continuation of previous travel speed studies conducted for the Phoenix urbanized area. The last of these comprehensive studies was conducted in 1986. Prior to the 1986 study, travel speed surveys were conducted in 1957, 1962, 1966, 1970, 1976, and 1979.

In the seven years since the completion of the 1986 travel speed study, the MAG region has continued its rapid growth. Additionally, numerous roadway improvements have been made including:

- Interstate 10 Inner Loop,
- Squaw Peak Parkway from I-10 to Northern Avenue,
- Red Mountain Freeway from I-10 to Priest Drive,
- Agua Fria Freeway (Loop 101) from 75th Avenue to Northern Avenue,
- Pima Freeway (Loop 101) from University Drive to Southern Avenue,
- Hohokam Expressway, and
- Superstition Freeway widening and extension.

To identify historical trends in travel speed in the MAG region, the travel speed data collected under this study were compared with previous data. Many of the street segments assessed under this study are compatible with previous studies. The 1957 study covered 151 miles of major streets within the City of Phoenix. The 1986 study covered 706 miles of major streets and 62 miles of freeways throughout the urban area. The 1993 study covers more than 800 miles of major streets and 100 miles of freeways.

Chapter II describes the methodology used to obtain the travel speed and signalized intersection delay data. Also included in the chapter are definitions of key terms and a discussion of the data analysis.

Chapter III presents the results of the 1993 travel speed data. Included in this chapter are figures showing the travel speed, running speed and stop delay for each segment analyzed. The average travel speeds are summarized by peak, jurisdiction, roadway functional class, and area type. Average running speeds and stop delay are summarized by roadway functional class and area type. Additionally, the average travel time between jurisdictions is presented.

The results of the signalized intersection stopped delay analysis are presented in Chapter IV, and comparisons of the 1993 travel speed data with historic travel speed data is presented in Chapter V.

II. METHODOLOGY

This chapter presents the methodology used to collect and analyze the travel speed data collected for the 1993 Travel Speed Study. Additionally, key analysis parameters are defined.

Definitions

Travel time is the total duration for a vehicle to travel over a section of roadway in a time period.

Running time is the duration during which a vehicle is in motion. The threshold speed for a vehicle in motion is five (5) mph.

Delay is time lost to travel due to:

- traffic friction/congestion,
- accidents/incidents,
- traffic control devices,
- emergency vehicles,
- trains, or
- pedestrians.

The threshold speed for a vehicle experiencing delay is five (5) mph.

Travel speed is the distance divided by the total travel time which includes running and delay times.

Running speed is the travel distance divided by the running time.

Mean travel speed is the distance divided by the mean travel time of several trips.

Mean running speed is the distance divided by the mean running time of several trips.

Spot speed is the instantaneous measure of speed at a specific location on a roadway.

Time mean speed is the arithmetic mean of several spot speed measurements.

Morning peak period is the time period 7:00 a.m. to 9:00 a.m. on a typical weekday (Monday through Friday).

Off peak period is the time period 10:00 a.m to 2:00 p.m. on a typical weekday.

Evening peak period is the time period 4:00 p.m. to 6:00 p.m. on a typical weekday.

Route Selection

Selection of routes for the 1993 travel speed survey was based upon a procedure agreed upon by MAG and Lee Engineering. Two sets of routes were developed for MAG review and selection. The first set included only minor arterial or higher roadway classifications, the second set also included major collectors. The set with urban collectors also included 24 miles of frontage roads. As discussed earlier, the routes selected included over 800 miles of arterial roadways and 100 miles of freeway and high occupancy vehicle (HOV) lanes. The first set of routes was selected by MAG for the 1993 travel speed study. These routes are shown in Figure 1. The number of miles surveyed by peak period, jurisdiction, and functional class are shown in Table 1, 2 and 3.

Route selection began with fourteen (14) significant routes identified by MAG for inclusion in the 1993 travel speed study. The remaining mileage was randomly selected in such a manner to balance the number of roadway miles for each classification in each area type. This was accomplished by developing a data entry program which allowed a route to be entered into a database in a link-by-link fashion with the MAG area type and MAG functional class. A subroutine was developed which output a matrix of roadway miles for each classification of each area type. Using this matrix, routes were selected in an iterative manner to obtain a balance of roadway miles between each cross-classification in the matrix.

Data Collection

Travel speed data collection was conducted using the floating-car technique in accordance wit the Manual of Traffic Engineering Studies (Studies Manual), Fourth Edition (1976). This is consistent wit the method used to collect travel speed data in the 1986 study. Using this technique, the driver floats with traffic by passing an equal number of vehicles as pass the test car. The Studies Manual discusses two methods for recording the results: manual operation or an automatic recording device. Manual operation requires two people for each test car in operation, a driver and a recorder. This was the method used to collect speed data for the 1986 study. However, for the 1993 study, data collection was conducted using Global Positioning System (GPS) technology and a small portable computer to automatically record the travel speed data. Using this method, only one person (the driver) was required. The GPS units were set to record the date, time, vehicle position (x,y,z coordinates), and instantaneous velocity of a vehicle every two seconds.

On each day of data collection, the data collectors met with Lee Engineering personnel to obtain a route, a vehicle, a GPS unit, and a Tandy 102 computer. Data collection activities were conducted for representative weekday conditions (Monday through Friday) for the following time periods.

- morning peak (7:00 a.m.-9:00 a.m.),
- off peak (10:00 a.m.-2:00 p.m.), and
- evening peak (4:00 p.m.-6:00 p.m.).

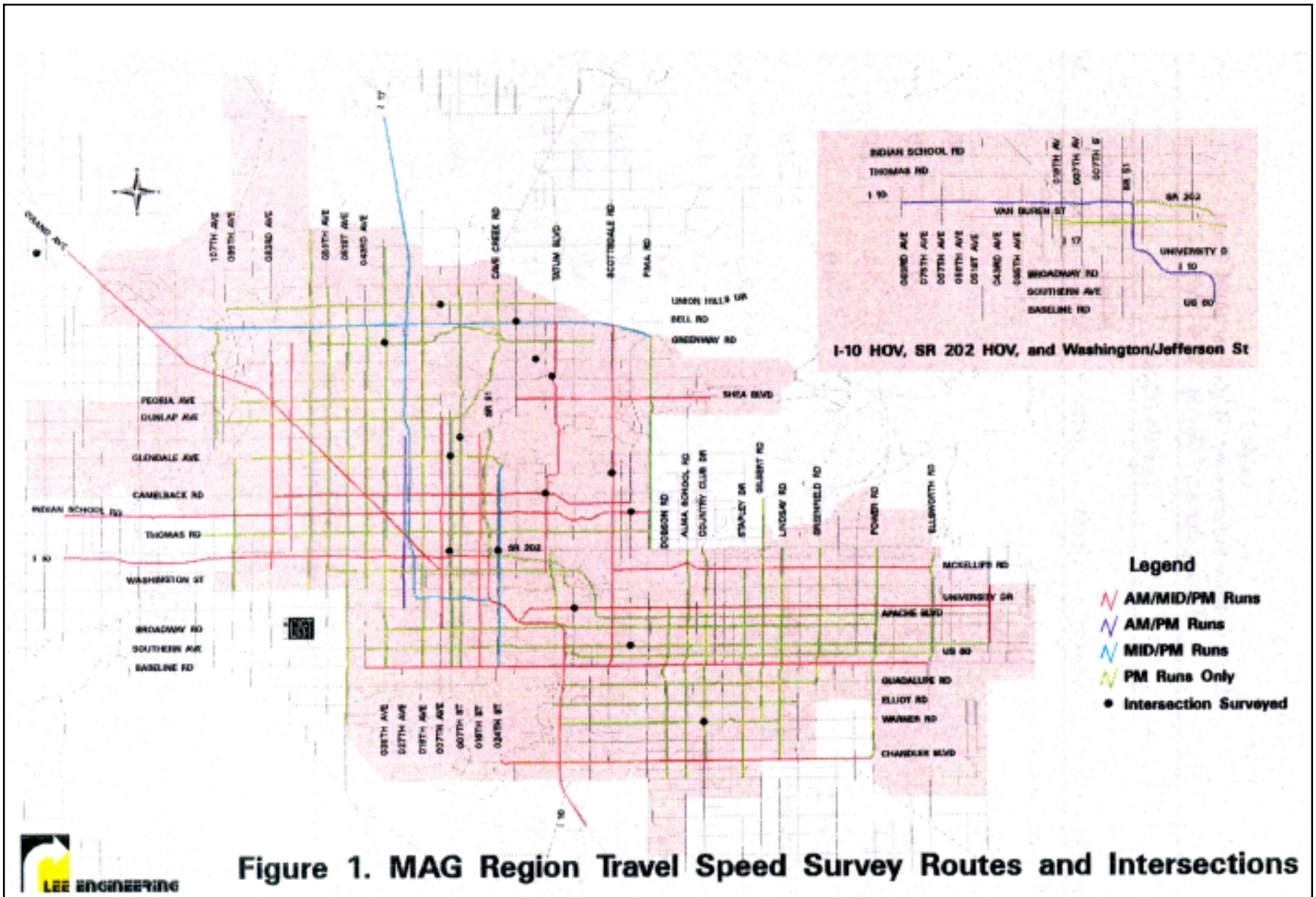


Figure 1. MAG Region Travel Speed Survey Routes and Intersections

Table 1
Miles of Road Surveyed by MAG Functional Class
Morning Period: 7:00 a.m.-9:00 a.m.

	Function Class					
Jurisdiction	Freeway	Grand	HOV	Minor Arterial	Principal Arterial	All
Apache Junction				2.5		2.5
Avondale	4.0					4.0
Chandler	2.7				9.0	11.7
County	2.1			9.0	7.0	18.1
Gilbert				3.1	2.0	5.1
Glendale		4.2		6.0		10.2
Goodyear	5.0				9.0	13.9
Mesa				16.1	17.0	33.1
Paradise Valley					4.1	4.1
Peoria		4.5		9.1		13.5
Phoenix	17.7	5.7	17.7	28.7	76.2	146.0
Scottsdale				1.0	25.2	26.2
Sun City		1.8				1.8
Surprise		5.8				5.8
Tempe	6.6		1.8		16.6	25.0
Tolleson	2.0					2.0
Youngtown		4.4				4.4
All	40.0	26.2	19.6	75.5	165.9	327.3

Table 2
Miles of Road Surveyed by MAG Functional Class
Midday Period: 10:00 a.m-2:00 p.m.

Jurisdiction	Functional Class				
	Freeway	Grand	Minor Arterial	Principal Arterial	All
Apache Junction			2.5		2.5
Avondale	4.0				4.0
Chandler	2.7			9.0	11.7
County	2.1		9.0	7.0	18.1
Gilbert			3.1	2.0	5.1
Glendale		4.2	6.0	3.0	13.1
Goodyear	5.0			9.0	13.9
Mesa			16.1	17.0	33.1
Paradise Valley				4.1	4.1
Peoria		4.5	9.0	1.0	14.6
Phoenix	44.8	5.7	19.7	101.0	171.1
Scottsdale			1.0	27.3	28.3
Sun City		1.8		3.0	4.8
Surprise		5.8		3.5	9.3
Tempe	6.6			16.6	23.1
Tolleson	2.0				2.0
Youngtown		4.4			4.4
All	67.1	26.2	66.5	203.3	363.1

Table 3
Miles of Road Surveyed by MAG Functional Class
Evening Period: 4:00 PM-6:00 PM

	Functional Class					
Jurisdiction	Freeway	Grand	HOV	Minor Arterial	Principal Arterial	All
Apache Junction				2.5		2.5
Avondale	4.0			2.0	4.0	10.0
Chandler	2.7			9.1	22.1	33.8
County	2.1			12.6	19.1	33.8
Gilbert				29.2	2.0	31.1
Glendale		4.2		27.8	31.6	63.6
Goodyear	5.0				9.0	13.9
Guadalupe				0.3		0.3
Mesa	15.0			68.3	64.1	147.5
Paradise Valley					4.1	4.1
Peoria		4.5		21.9	1.0	27.4
Phoenix	66.1	5.7	17.7	110.1	239.9	439.4
Scottsdale				1.0	41.6	42.6
Sun City		1.8		5.1	3.0	9.9
Surprise		5.8			3.5	9.3
Tempe	12.8		1.8	18.4	31.4	64.5
Tolleson	2.0				1.0	3.0
Youngtown		4.4				4.4
All	109.6	26.2	19.6	308.3	477.3	941.0

To collect travel speed data, the data collectors proceeded to the starting location of the route. Prior to beginning the travel speed run, the GPS unit was initialized and a file created to store the date, time, position, and velocity data. At the end of each data collection period, the unit was turned off and returned to Lee Engineering where the data was downloaded to a personnel computer. Data collectors were instructed to drive primarily in the second or third lanes, to avoid right turn and bus operation interference. The drivers were also instructed to travel at the posted speed limit in those cases where there was little or no traffic.

Each vehicle was also equipped with a Tandy 102 computer, which was used to collect data identifying the time and type of delays encountered along the route as well as construction zone limits. While driving the route, the data collector pressed a key whenever delay was encountered (speed fell below 5 miles per hour) for delay types other than intersection delay. Careful consideration was given to categorizing the types of delay so that remembering the classifications and corresponding key would not be difficult. The delay types identified for data collection included:

- Accident
- School Zone
- Begin Construction Zone
- End Construction Zone
- Pedestrian
- Emergency Vehicle
- Trains
- Other

In addition to identifying delay type, the starting and ending time of the run were collected by the Tandy 102 computers. At the end of each day, the files containing the delay information were downloaded from the Tandy 102 computers to a personnel computer. The GPS data and Tandy data were then analyzed as described in the next section.

Analysis

Reduction and analysis of these data were achieved through a carefully designed data analysis procedure which took full advantage of an integrated GIS, database and statistical analysis software system. Most of the data conversion and manipulation was performed through programming in FoxPro 2.5 on the DOS platform. This provided an interface with PC SAS (Statistical Analysis Package) for statistics analysis as well as an interface with Arc/Info on the Sun Station for final spacial analysis and graphics reports.

Each route included in the travel speed survey was divided into links (defined as a route section bounded by two cross streets with a MAG functional classification of Minor Arterial or higher). For each link, a number of descriptive variables were defined directionally by peak period for analysis purposes. These variables are described below.

Average Travel Time for each link was calculated as the mean of all travel time runs for a segment. To determine travel time, it was necessary to determine the time that the vehicle passed through the

intersections (control nodes) defining the endpoints of the link. Intersection coordinates were determined from the Arc/Info coverage obtained from MCDOT for each intersection of interest. An interpolation process was used to determine the time that the vehicle passed through the intersections bounding the link. This process was accomplished using the coordinate data and time data collected on a two second interval during the travel speed run.

Average Travel speed for each link was calculated for the mean of the three runs for each period by dividing the length of the link by the mean total travel time on the link. The length of the link was defined as discussed below.

Travel speed error was calculated on mean travel time and converted to a range for mean travel speed. The error for mean travel time was calculated using the following equation:

$$? = t_a \times \frac{S}{\sqrt{n}}$$

where,

?= error of the mean at the chosen confidence level,
t_a= the 95 percentile of the t-distribution with n-1 degrees of freedom,
S= the standard deviation of the sample,
n= the sample size.

The 95% confidence interval for mean travel time was converted to a range for travel speed. The target tolerance was a range of 6 mph. Three (3) travel speed runs were initially performed for each route for each designation time period. Any routes that experienced non-recurring delay may have been deleted from the tolerance calculation. If the target tolerance was not achieved as a result of the initial runs, additional runs were performed until the target tolerance was achieved. If additional runs were required, the tolerance was calculated from data collected for all runs. No run data were thrown out or replaced by data collected from additional runs. A maximum of 3 additional runs may have been performed to each route for each designated time period.

Number of lanes were collected in the field at each signalized intersection along the designated routes. The number of left turn, through, and right turn lanes were collected at the end of the segment.

Average Running speed was calculated for the mean of the total number of runs for each period by dividing the length of the link by the mean running time (time when the vehicle is traveling at a speed greater than five miles per hour). The running time for each link was obtained from the GPS output as the travel time minus any delay time. The mean running speed was determined from the three travel runs.

Average Stop Delay was also calculated from the GPS data. Delay was determined by summing the time that the vehicle was traveling at a speed of less than five miles per hour. The type of delay occurring was identified based on data collected with the Tandy 102 computers.

Length of the link segment was determined from an ARC/INFO roadway centerline file obtained from the Maricopa County Department of Transportation.

Jurisdiction of the link was determined from a map showing the city limit boundaries.

Functional class was obtained from MAG. These classes included freeways, high occupancy vehicle (HOV) lanes, principal arterials, and minor arterials. Also at the request of MAG, Grand Avenue was identified as its own functional class. The functional class for each link is shown in Figure 2.

Area type was obtained from data provided by the MAGTPO. Area type ranges from 1 (highly developed) to 5 (minimal development). The area type for each link is shown in Figure 3.

Signal density was field collected. A data collector was assigned the task of identifying signalized intersections along all routes included in the study. The number of signals on a per mile basis were determined for each link. The type of traffic signal control was also recorded (2-phase, 8-phase, protected-permissive, protected only).

Posted speed limit was also field collected. These data were collected along with the signal density.

ADT volumes were collected for each link of each designated route. The volumes were obtained from several sources including: City counts, City volume maps, MAG volume maps, and ADOT traffic counts available in Traffic on the Arizona State Highway System, 1992.

Vehicle Miles Traveled (VMT) was calculated by multiplying the ADT volume with the length of the roadway segment.

Average Travel Speed by Jurisdiction was calculated as the inverse of the weighted average (using vmt) of the inverse of the travel speeds for the segments in a jurisdiction. This represents the average speed of traffic traveling on the street network within a jurisdiction.

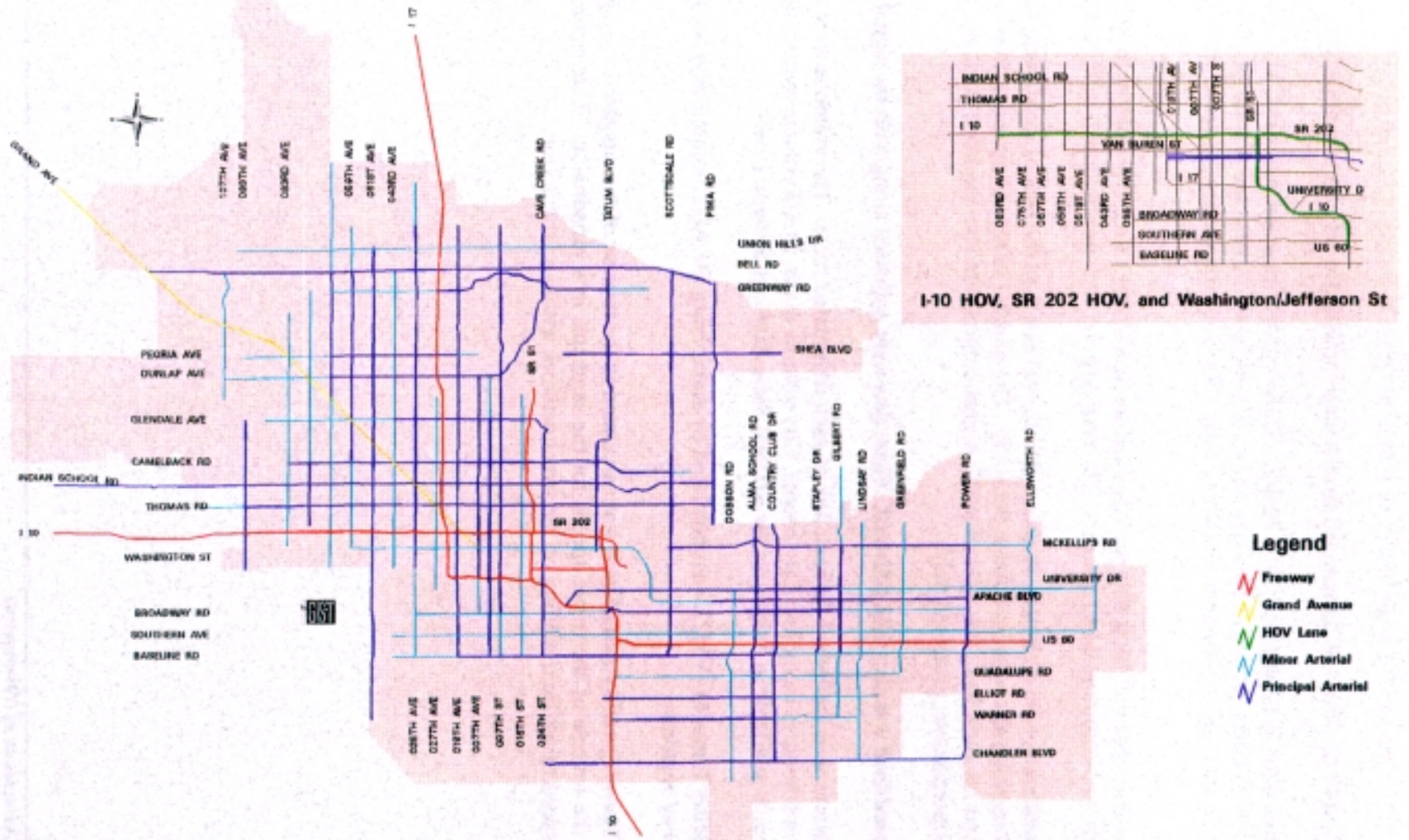


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Figure 2. MAG Region Travel Speed Survey Roadway Functional Class

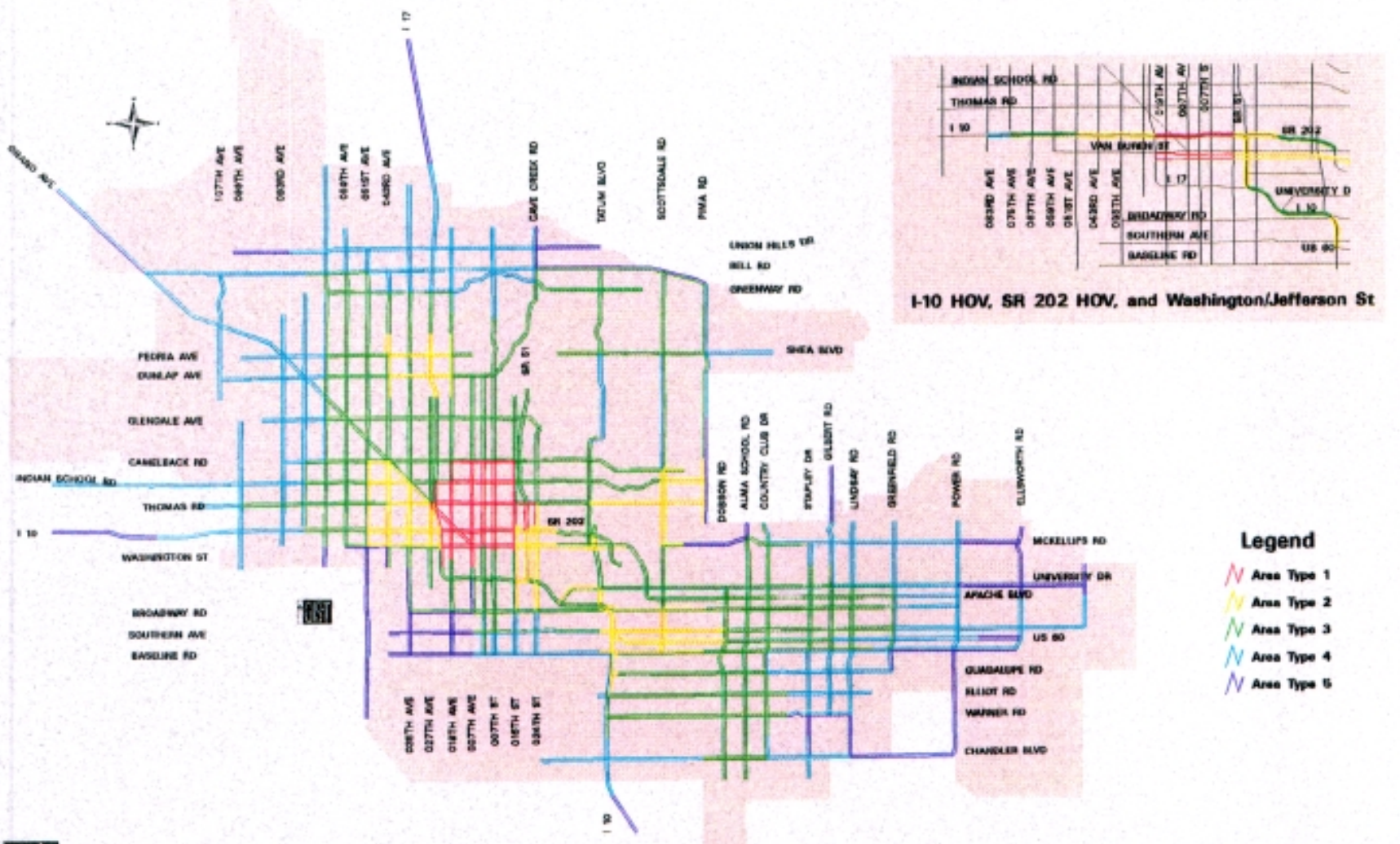

Figure 3. MAG Region Travel Speed Survey Roadway Area Type

III. 1993 SPEEDS AND TRAVEL TIMES

The results of the 1993 Travel Speed Study are presented in this chapter. More than 800 miles of arterial roadways and 100 miles of freeways and HOV lanes were surveyed as part of this study. Travel speeds, running speeds, and stop delay are presented by analysis period and street segment. Average travel speeds are presented by jurisdiction, functional class and area type for each analysis period. Average running speeds are also presented by functional class and area type for each analysis period. Additionally the travel times between major valley central business districts are examined and presented along with contour maps showing the travel times from central Phoenix and Sky Harbor International Airport.

Average Travel Speed by street Segment and MAG Functional Class

The average travel speed for each roadway segment surveyed as part of the 1993 travel speed study is shown in Figure 4, 5, and 6. During the morning, midday, and evening periods, approximately 11, 10, and 16 percent of the roadway links surveyed can be defined as slow (speeds less than 25 miles per hour), respectively.

During the morning, midday, and evening peak period, many of the slow speeds occur on roadways in central Phoenix, the east valley, and Scottsdale. Of the routes surveyed, the highest number of miles of slow segments occurred in Phoenix with nearly 29, 31, and 121 miles of roadway segments incurring travel speeds below 25 miles per hour during the morning, midday, and evening periods, respectively. This is to be expected however as Phoenix contained the largest sampling of roadways with 146 miles of roadway surveyed during the morning period, 171 miles surveyed during the midday period, and 439 miles surveyed during the pm period. This accounts for 45%, 47%, and 47% of the total roadway miles surveyed during the morning, midday, and evening periods respectively.

During the morning peak period, over 20 percent of the routes surveyed in Sun City, Peoria, Tempe, and Scottsdale experienced travel speed below 25 miles per hour. During the midday period more than 50 percent of the roadway miles surveyed in Sun City, Apache Junction, and Youngtown experienced travel speeds less than 25 miles per hour. However, these jurisdictions combined account for only 6 percent of the roadway miles surveyed during this period. During the evening peak period, more than 20 percent of the roadway miles surveyed in Sun City, Scottsdale, Peoria, and Tempe have travel speed of less than 25 miles per hour.

During the morning and evening periods may of the roadway segments crossing Grand Avenue and I-17 have speeds of 25 miles per hour or less. The speed is above 50 miles per hour during the midday period for nearly all surveyed segments of the freeway system. A review of the travel speeds fro the freeway system during the evening peak period show that most segments operate with speeds above 50 miles per hour. However, travel speeds on northbound I-17 through central Phoenix are generally well below 50 miles per hour as well as speeds on eastbound I-10 between 24th Street and the Superstition Freeway. On eastbound I-10 between the Hohokam Freeway and the Superstition Freeway, the evening travel speed is less than 25 miles per hour.

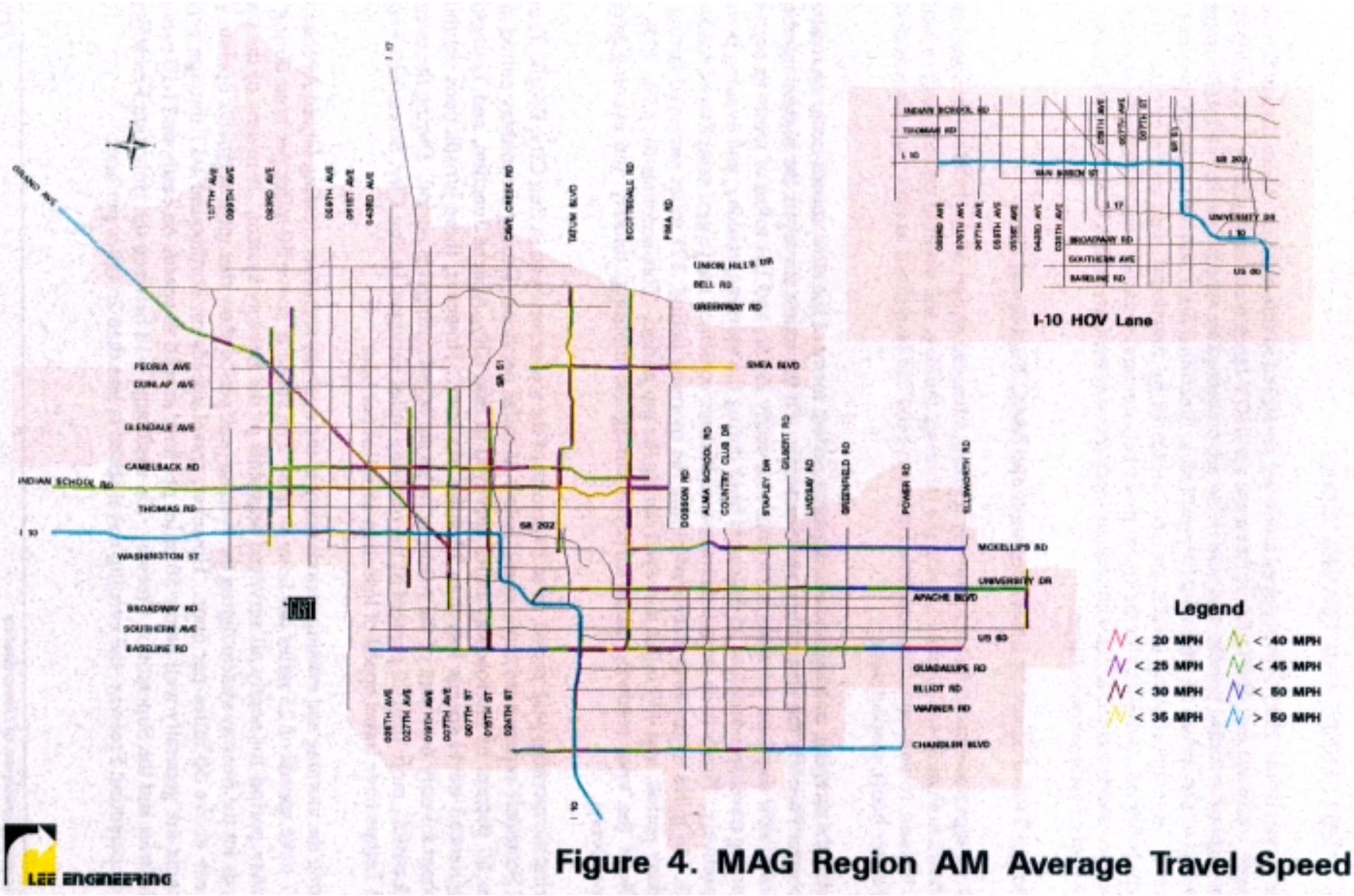

Figure 4. MAG Region AM Average Travel Speed

Figure 5. MAG Region Mid-day Average Travel Speed

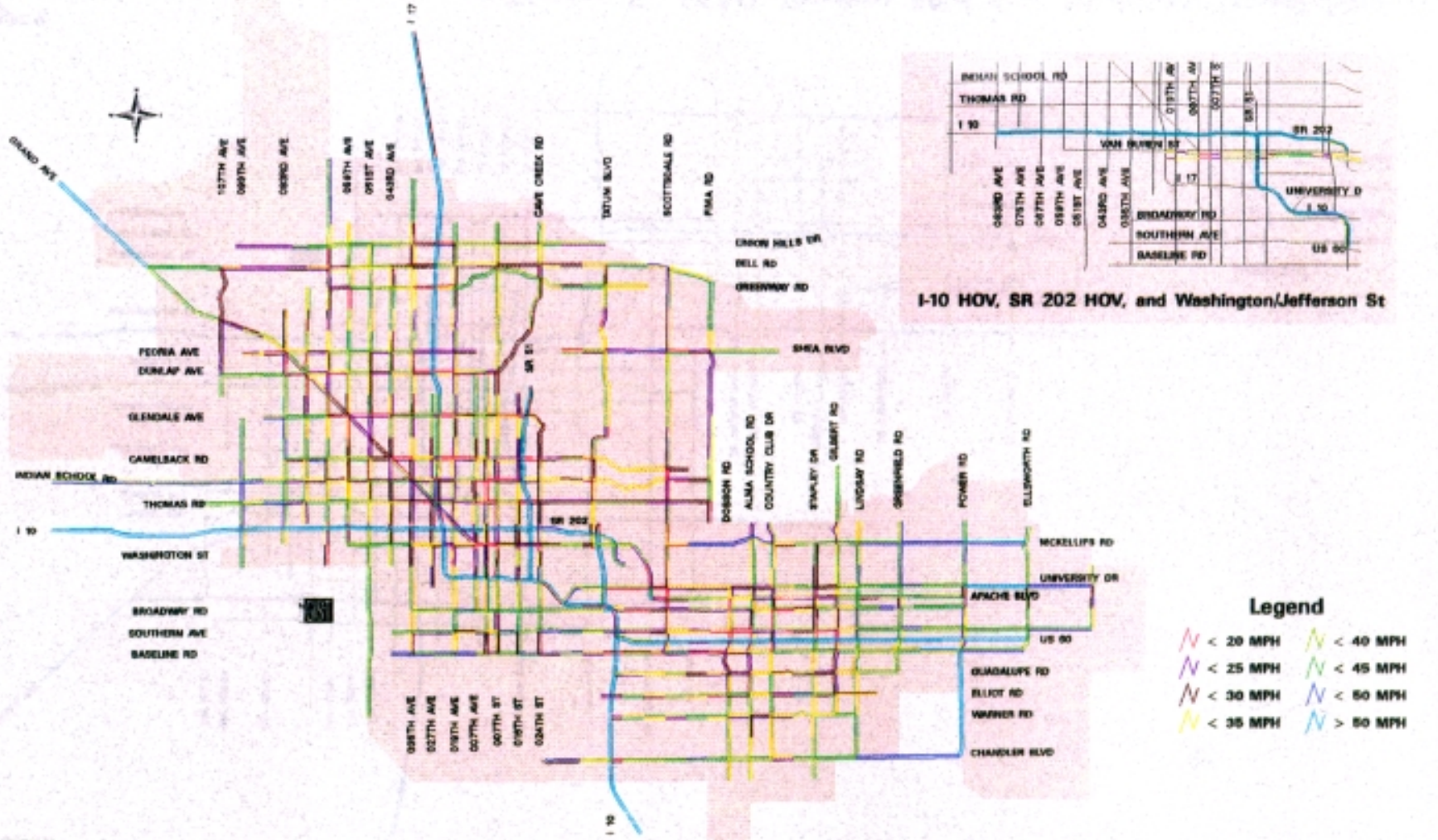

Figure 6. MAG Region PM Average Travel Speed

A review was also made of the average travel speeds by MAG functional class, area type and number of lanes. These speeds are shown for the morning, midday, and afternoon peak periods in Table 4, 5, and 6, respectively. To tabulate the data, five functional classes were used. These functional classes include freeway mainline and HOV lanes, principal arterials, minor arterials, and Grand Avenue. At the request of MAG, Grand Avenue was treated as a separate functional class. Additionally, five area types were used. Area type is one of the inputs to the MAG travel forecast model and describes a degree of population and employment density. Area type 1 represents the most dense population and employment and area type 5 the least.

As shown in the tables, the mean travel speed for all functional classes, area types and number of lanes in nearly identical during the morning and midday periods. The average system travel speed during the morning period is 42.7 miles per hour while the midday average system travel speed is 42.5 miles per hour. The average system travel speed during the evening peak is less at 39.7 miles per hour.

The average freeway travel speed during the morning, midday, and evening peak periods is 56.7, 60.7, and 53.6 miles per hour, respectively. The average travel speed on an HOV lane during the morning period is 63.7 miles per hour and 61.9 miles per hour during the evening peak period. HOV lanes were not included in the midday sample. The average travel speed on principal and minor arterials remain fairly constant throughout the day. The average system travel speeds for principal arterials during the morning, midday, and evening periods are 32.0, 33.1, and 29.8 miles per hour, respectively. The average travel speeds for minor arterials during the morning, midday, and evening periods are 32.0, 33.1, and 29.8 miles per hour respectively. The average travel speeds for minor arterials during the morning, midday, and evening periods are 33.4, 33.8, and 31.5 miles per hour, respectively.

Running Speeds by Street Segment and MAG Functional Class

The average running speed for each roadway segment surveyed for the 1993 travel speed study are shown in Figures 7, 8, and 9. As discussed in Chapter II, running speed defined as the length of a roadway segment divided by the time required to traverse the segment during which the vehicle is in motion (speed greater than 5 miles per hour). Simply, running speed is the speed at which a motorist could expect to travel a given roadway segment without experiencing any stop delay (speed less than 5 miles per hour).

Nearly all of the roadways surveyed during the morning, midday, and evening peak traffic periods showed running speeds greater than 25 miles per hour. Only 1 percent of the roadway miles surveyed during the morning peak incurred 'slow' running speeds (running speed < 25 miles per hour). Less than 1 percent of the roadway miles surveyed in the midday period incurred 'slow' running speeds, and less than 2 percent of the roadway miles surveyed in the evening period incurred slow running speeds. A review of the segments with low running speeds indicates that the segments experience 'slow' running speeds are generally located in Phoenix, Scottsdale, and the east valley.

Table 4
Mean Travel Speed by MAG Functional Class
Morning Period: 7:00 a.m-9:00 a.m.

	Area Type																				
	1					2					3					4			5		
	Number of Lanes					Number of Lanes					Number of Lanes					Number of Lanes			Number of Lanes		
Functional Class	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	1	2	All
Freeway				59.8	64.4		58.1	37.5	59.5	60.6		31.6	47.3	64.0	62.0		65.0	62.8		65.1	56.7
Grand Avenue			32.0					41.2					26.8			54.9	38.2	34.8		55.6	40.5
HOV Lane	63.1					61.3					63.9					66.7					63.7
Minor Arterial		32.1	25.2				33.4	25.1			26.5	32.7	31.1			30.9	37.9	38.3	43.0	44.0	33.4
Principal Arterial		24.5	32.0	29.2			28.2	27.1				31.5	30.9	18.8		36.1	38.0	35.7	44.1	40.4	32.0
All	63.1	28.3	29.7	44.5	64.4	61.3	39.9	32.7	59.5	60.6	45.2	31.9	34.0	41.4	62.0	47.2	44.8	42.9	43.6	51.3	42.7

Table 5
Mean Travel Speed by MAG Functional Class
Midday Period: 10:00 a.m. -2:00 a.m.

	Area Type																				
	1				2				3				4			5					
	Number of Lanes				Number of Lanes				Number of Lanes				Number of Lanes			Number of Lanes					
Functional Class	2	3	4	5	2	3	4	5	2	3	4	5	1	2	3	1	2	3	All		
Freeway		51.3	62.4	50.4	56.7	61.9	61.0	64.1	59.9	58.4	66.2	63.3		63.9	64.4		65.5		60.7		
Grand Avenue		33.5				36.9				30.3			54.7	31.6	34.6		51.5		39.0		
Minor Arterial	28.0	26.7			32.6	28.3			31.0	33.3			31.3	37.7	41.3	37.3	43.7		33.8		
Principal Arterial	23.9	29.2	35.3		27.5	27.5			33.5	30.4	15.3		38.6	35.7	35.5	45.7	40.1	45.0	33.1		
All	25.9	35.2	48.8	50.4	38.9	38.6	61.0	64.1	41.5	38.1	40.7	63.3	41.5	42.2	44.0	41.5	50.2	45.0	42.5		

Table 6

Mean Travel Speed by MAG Functional Class
Evening Period: 4:00 pm.-6:00 p.m.

	Area Type																					
	1					2					3					4				5			
	Number of Lanes					Number of Lanes					Number of Lanes					Number of Lanes				Number of Lanes			
Functional Class	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	1	2	3	All
Freeway			43.6	45.2	63.2	62.4	50.1	57.1	41.2	63.0	58.8	51.4	53.7	40.5	41.0		63.0	62.4			51.2	63.7	53.6
Grand Avenue			28.7					28.6					25.0			56.8	34.7	33.2			57.4		37.8
HOV Lane	62.1					59.7					61.1					64.6							61.9
Minor Arterial		24.2	25.6			33.2	27.3	23.0			33.1	30.7	28.1			30.2	35.1	33.0		33.4	41.7	42.5	31.5
Principal Arterial		25.2	23.6	33.7	22.8	39.4	25.9	27.4	27.6	34.5	24.4	29.8	28.3	17.9		30.9	33.7	33.5	26.2	33.8	42.1	35.3	29.8
All	62.1	24.7	30.4	39.4	43.0	48.7	34.5	34.0	34.4	48.8	44.4	37.3	33.8	29.2	41.0	45.6	41.6	40.5	26.2	33.6	48.1	47.2	39.7

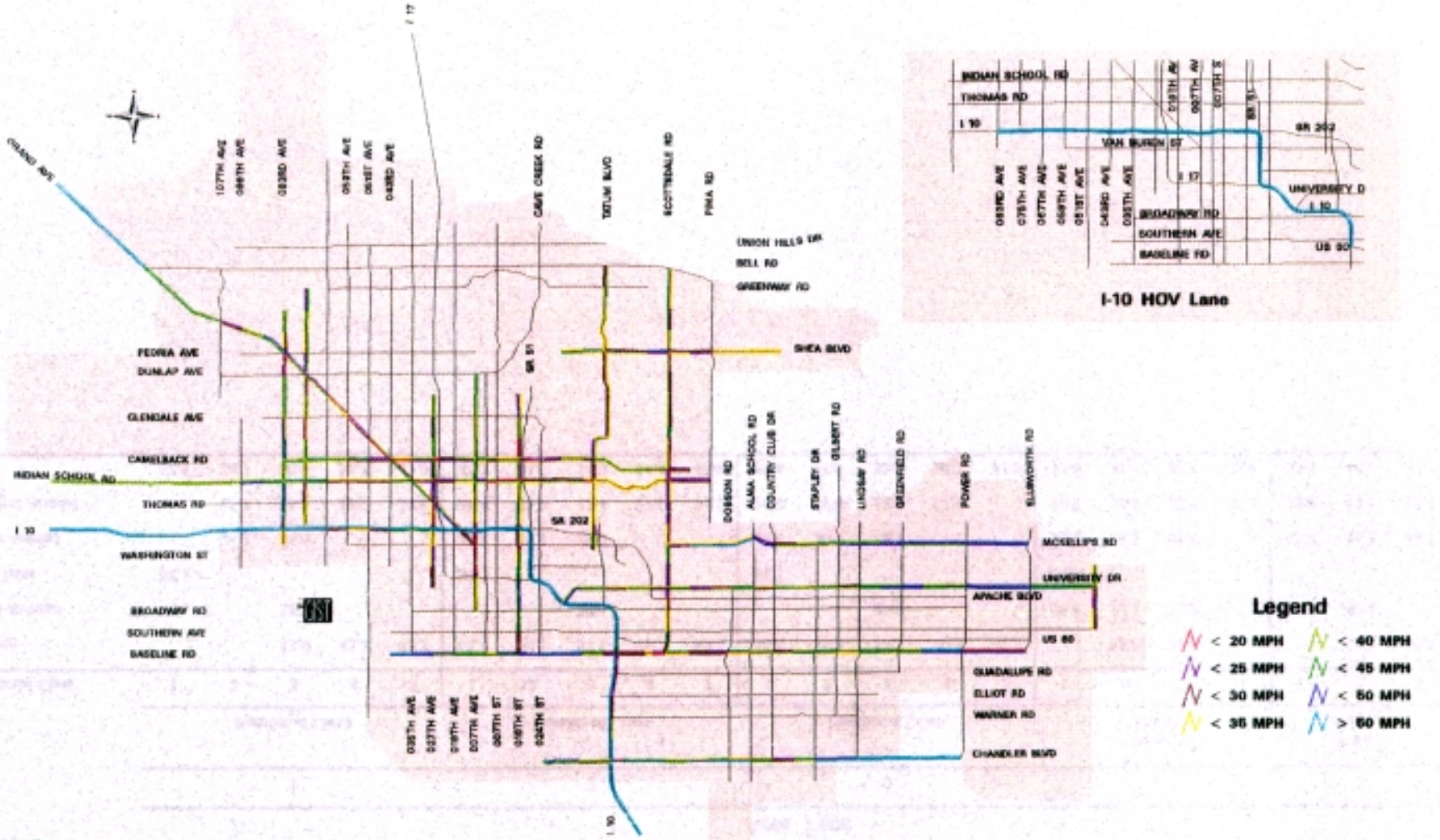

Figure 7. MAG Region AM Average Running Speed

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Figure 8. MAG Region Mid-day Average Running Speed

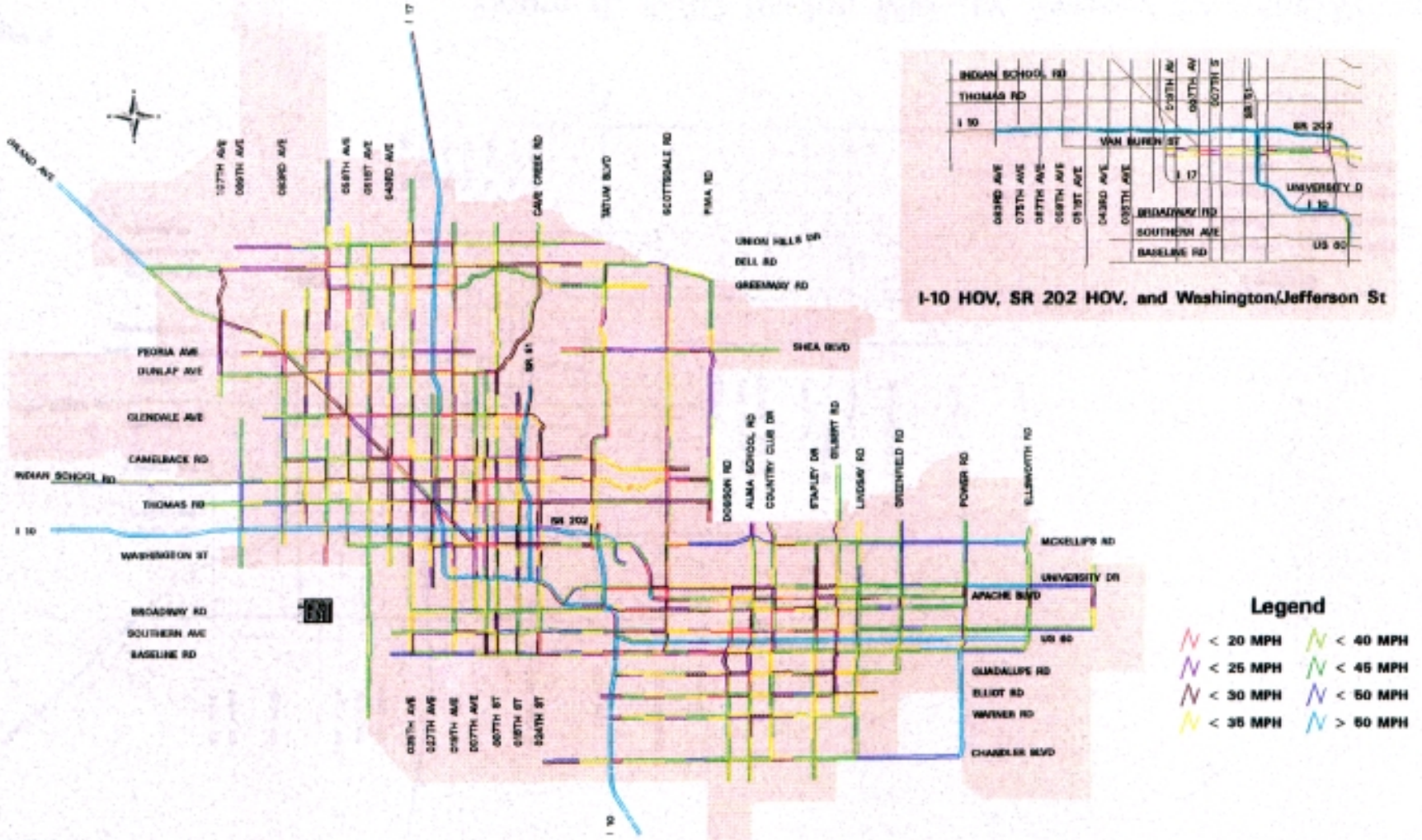

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Figure 9. MAG Region PM Average Running Speed

During the morning period, Interstate 10 between Elliot Road and the Broadway Curve experienced an average running speed of less than 25 miles per hour. All other freeways surveyed during this period had average running speeds greater than 25 miles per hour. All freeway segments surveyed during the midday period had running speeds greater than 25 miles per hour with nearly all segments having average running speeds greater than 50 miles per hour. During the evening period, all freeway links incur running speeds greater than 25 miles per hour, with most segments being greater than 50 miles per hour except for Interstate 10 eastbound approaching the SR 143 (Hohokam Freeway) to US 60 (Superstition Freeway). Running speeds along this segment are below 25 miles per hour.

It would be expected that since running speeds do not include stop delay that there would be no segments with running speeds less than 25 miles per hour. However, at locations with high traffic volumes, general congestion can create a situation where low running speed occur. Additionally, construction zones may also cause running speeds to decrease.

An review was also made of the average running speeds by MAG functional class, and area type. These speeds are shown for the morning, midday, and afternoon peak periods in Table 7,8, and 9, respectively.

As shown in the tables, the mean travel speed for all functional classes, area types and number of lanes remains fairly constant throughout the day. The average system running speeds during the morning, midday, and evening periods are 48.1, 45.1, and 45.9 miles per hour respectively.

The average freeway running speed during the morning, midday, and evening peak periods is 58.8, 62.3, and 54.6 miles per hour, respectively. The average running speed on an HOV lane during the morning period is 63.7 miles per hour and 61.9 miles per hour during the evening peak period. These speeds are identical to the average travel speeds during the same time periods. HOV lanes were not included in the midday sample. The average running speed on principal and minor arterials remain fairly constant throughout the day. The average system travel speeds for principal arterials during the morning, midday, and evening periods are 38.8, 37.7, and 36.9 miles per hour, respectively. The average travel speeds for minor arterials during the morning, midday, and evening periods are 39.2, 38.0, and 36.0 miles per hour, respectively.

Freeflow Speeds by Functional Class

Average freeflow speeds were also determined based on MAG functional class. To calculate freeflow speeds, travel speeds were averaged for roadway segments which were not anticipated to be congested. To select these segments, it was assumed that the peak hour volume was 9 percent of the ADT volume. A segment was classified as non congested if the peak hour volume divided by the number of lanes was less than 1000 vehicles per hour per lane (vphpl) on arterial streets and 1400 vphpl on freeways and HOV lanes.

Table 7
Mean Running Speed by MAG Functional Class
Morning Period: 7:00 a.m.-9:00 a.m.

	Area Type					
Functional Class	1	2	3	4	5	All
Freeway	61.2	49.2	54.9	63.4	65.1	58.8
Grand Avenue	40.6	41.5	35.7	42.0	55.6	43.1
HOV Lane	63.1	61.3	63.9	66.7		63.7
Minor Arterial	35.9	36.1	37.7	40.9	45.5	39.2
Principal Arterial	34.2	34.1	36.8	40.8	48.1	38.8
All	47.0	44.4	45.8	50.7	53.6	48.1

Table 8
Mean Running Speed by MAG Functional Class
Midday Period: 10:00 a.m.-2:00 p.m.

	Area Type					
Functional Class	1	2	3	4	5	All
Freeway	58.9	61.8	60.9	64.3	65.6	62.3
Grand Avenue	39.3	40.3	40.0	40.9	51.5	42.4
Minor Arterial	33.1	36.2	36.7	40.5	43.8	38.0
Principal Arterial	33.5	33.1	37.4	40.2	44.5	37.7
All	41.2	42.8	43.7	46.4	51.4	45.1

Table 9
Mean Running Speed by MAG Functional Class
Evening Period: 4:00 p.m.-6:00 p.m.

	Area Type					
Functional Class	1	2	6	4	5	All
Freeway	48.8	53.4	52.1	62.6	56.1	54.6
Grand Avenue	40.1	38.6	38.6	41.7	57.4	43.3
HOV Lane	62.1	59.7	61.1	64.6		61.9
Minor Arterial	29.9	34.5	36.8	38.8	39.9	36.0
Principal Arterial	32.2	34.8	35.4	39.1	42.8	36.9
All	42.6	44.2	44.8	49.4	49.0	45.9

The average freeflow speeds determined from travel speed data are presented in Tables 10, 11, and 12. As shown in the Tables, the freeflow speeds for all roadways surveyed remained fairly constant during all periods ranging from a high of 42 miles per hour during the morning period to a low of 39 miles per hour during the midday period.

The lowest calculated freeflow speeds were experienced on minor arterials with speeds of 33, 35, and 32 miles per hour during the morning, midday, and evening periods, respectively. Slightly higher freeflow speeds were experienced on principal arterials with freeflow speeds of 36, 35, and 33 miles per hour during the morning, midday, and evening periods. Freeflow speeds on Grand Avenue were the highest of the three arterial functional classes. Freeflow speeds on Grand Avenue were 41, 40, and 38 miles per hour during the morning, midday, and evening periods, respectively.

Stop Delay by Street Segment

The average amount of stop delay measured on each roadway segment included in the 1993 travel speed study is shown in Figure 10, 11, and 12. As shown in the figures, the majority of roadway segments surveyed experience less than one-half minute of stop delay.

During the morning and midday periods, less than 8 percent of the roadway miles surveyed have stop delays of greater than 30 seconds. During the morning period, the roadways experiencing the most stop delay include Grand Avenue, Tatum Boulevard south of She Boulevard, McKellips Road between Scottsdale Road and Alma School Road, and Camelback Road and Indian School Road east of Tatum Boulevard. The roadways experiencing the most stop delay during the midday peak include Grand Avenue, Bell Road, Camelback Road, Indian School Road, 83rd Avenue south of Grand Avenue, and 16th Street.

During the evening period, less than 24 percent of the roadway miles surveyed have stop delays greater than 30 seconds. The roadways experiencing the most stop delay during the evening peak include Grand Avene and many of the roadway segments crossing Grand Avenue, She Boulevard, Camelback Road, Indian School Road, and many other roadway segments scattered throughout the study area.

Average stop delay was also tabulated on a per mile basis by analysis period, MAG functional class, area type, and type of delay (recurring or nonrecurring). By definition, recurring delays are delays which occur very regularly by location and time of day. These delays include general intersection congestion and school zone related delays. Non recurring delays are sporadic and occur without regular schedule. These delays are primarily incidence related and may include delays due to an accident, emergency vehicle, or very short term construction.

The stop delay, expressed on a per mile basis, for the morning, midday, and evening periods are shown in Table 13, 14, and 15, respectively. As shown in the tables, most of the delays encountered in the travel speed runs were recurring in nature. During all periods, the average non recurring delay for any facility type was nearly 0 seconds per mile.

Table 10
Mean Freeflow Speeds: PHF = 0.9 Threshold = 1000 vphpl (Freeways=1400 vphpl)
Morning Period: 7:00 a.m.-9:00 a.m.

	Area Type															
	1			2			3				4			5		
	Number of Lanes			Number of Lanes			Number of Lanes				Number of Lanes			Number of Lanes		
Functional Class	1	3	4	1	2	3	1	2	3	4	1	2	3	1	2	All
Freeway												68.0	63.7		64.8	65.5
Grand Avenue		32.0				41.2			26.8		54.9		34.8		55.6	40.9
HOV Lane	63.1			61.3			63.9				66.7					63.7
Minor Arterial		25.2			30.7	25.1	26.5	32.8	31.1		31.5	38.6	38.3	43.0	44.0	33.3
Principal Arterial		32.1	29.2		30.8	34.9		34.7	35.5	24.9	39.0	44.8	40.4		52.1	36.2
All	63.1	29.7	29.2	61.3	30.8	33.7	45.2	33.7	31.2	24.9	48.0	50.4	44.3	43.0	54.1	41.8

Table 11
Mean Freeflow Speeds: PHF = 0.9 threshold = 1000 vphpl (Freeways = 1400 vphpl)
Midday Period: 10:00 a.m.-2:00 p.m.

	Area Type													
	1		2		3			4			5			
	Number of Lanes		Number of Lanes		Number of Lanes			Number of Lanes			Number of Lanes			
Functional Class	3	4	2	3	2	3	4	1	2	3	1	2	3	All
Freeway									67.1	63.2		61.7		64.0
Grand Avenue	33.5			36.9		30.3		54.7		34.6		51.5		40.2
Minor Arterial	26.7			28.3	32.4	33.3		31.8	37.9	41.3	37.3	43.7		34.8
Principal Arterial	32.2	35.3	31.0	27.0	30.1	36.7	21.6	38.4	34.4	38.6		50.0	45.0	35.0

All			30.8	35.3	31.0	30.7	31.3	33.4	21.6	41.6	46.5	44.4	37.3	51.7	45.0	38.9					

Table 12
Mean Freeflow Speeds: PHF = 0.9 Threshold = 1000 vphpl (Freeways = 1400 vphpl)
Evening Period: 4:00 p.m.-6:00 p.m

Area Type																					
	1					2					3				4				5			
	Number of Lanes					Number of Lanes					Number of Lanes				Number of Lanes				Number of Lanes			
Functional Class	1	2	3	4	5	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	All
Freeway			56.8			62.4					58.8	19.2	57.2			66.9	62.4			68.8	63.7	57.4
Grand Avenue			28.7					28.6					25.0		56.8		33.2			57.4		38.3
HOV Lane	62.1					59.7					61.1				64.6							61.9
Minor Arterial		19.0	25.6			33.2	34.5	21.7			34.0	33.3	30.2		30.7	35.4	33.0		34.2	41.7	42.5	32.1
Principal Arterial		27.2	26.8	33.7	22.8		31.6	30.6	27.6	34.5	36.0	31.6	32.5	23.5	41.9	37.4	34.1	26.2	39.5	46.9	35.3	32.6
All	62.1	23.1	34.5	33.7	22.8	51.8	33.1	26.9	27.6	34.5	47.5	28.0	36.2	23.5	48.5	46.6	40.7	26.2	36.8	53.7	47.2	39.7

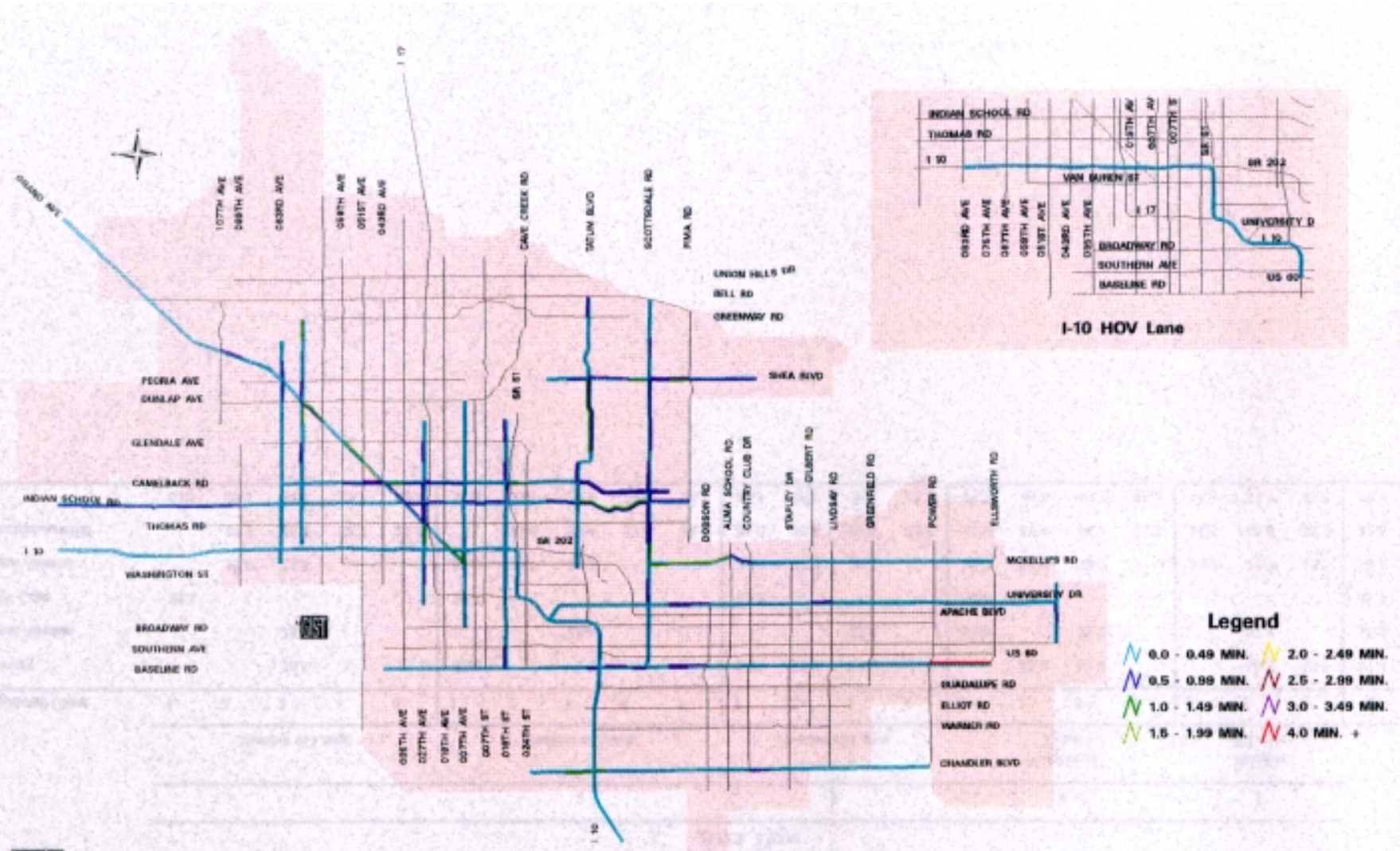


Figure 10. MAG Region AM Average Stop Delay

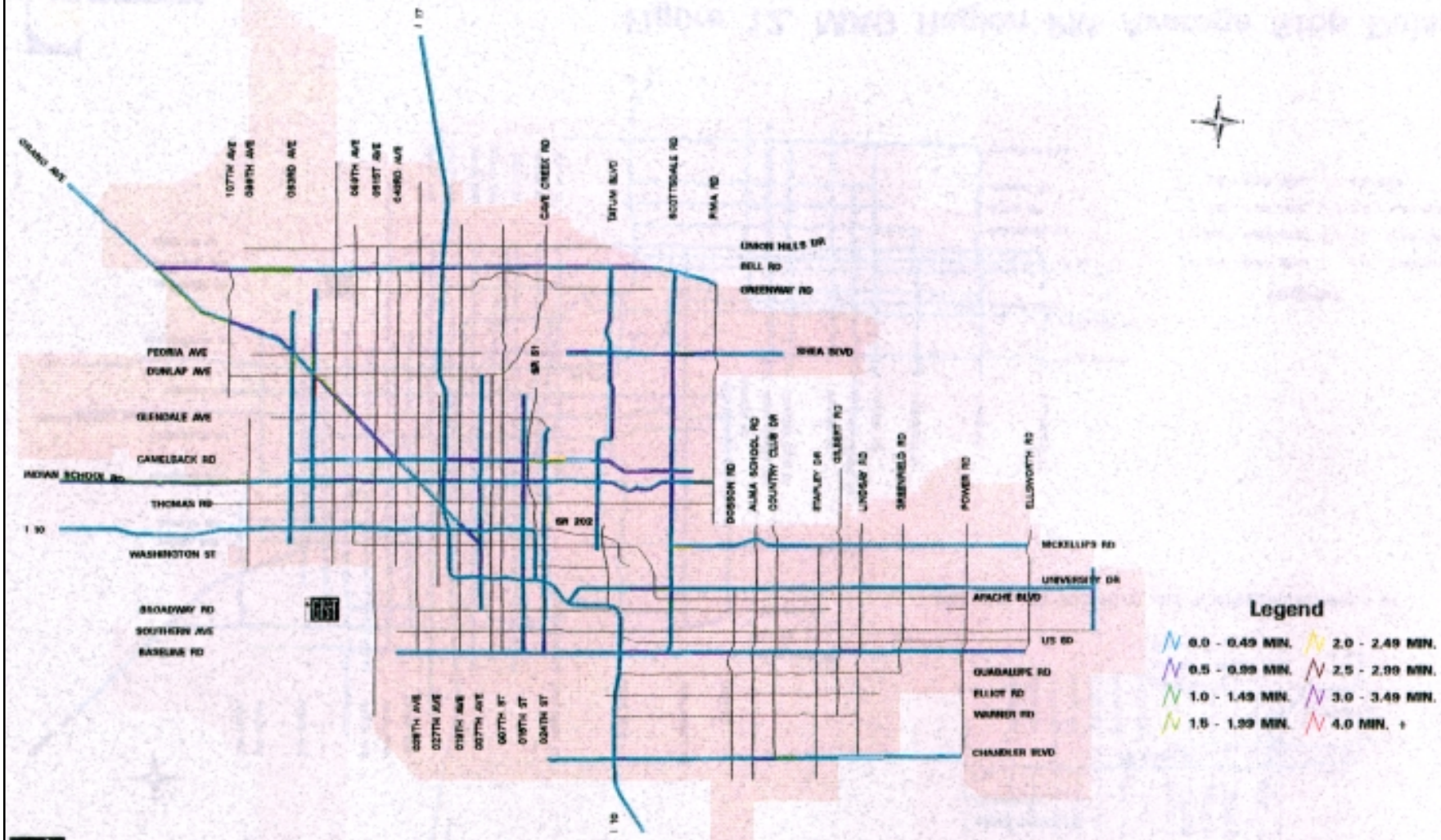


Figure 11. MAG Region Mid-day Average Stop Delay

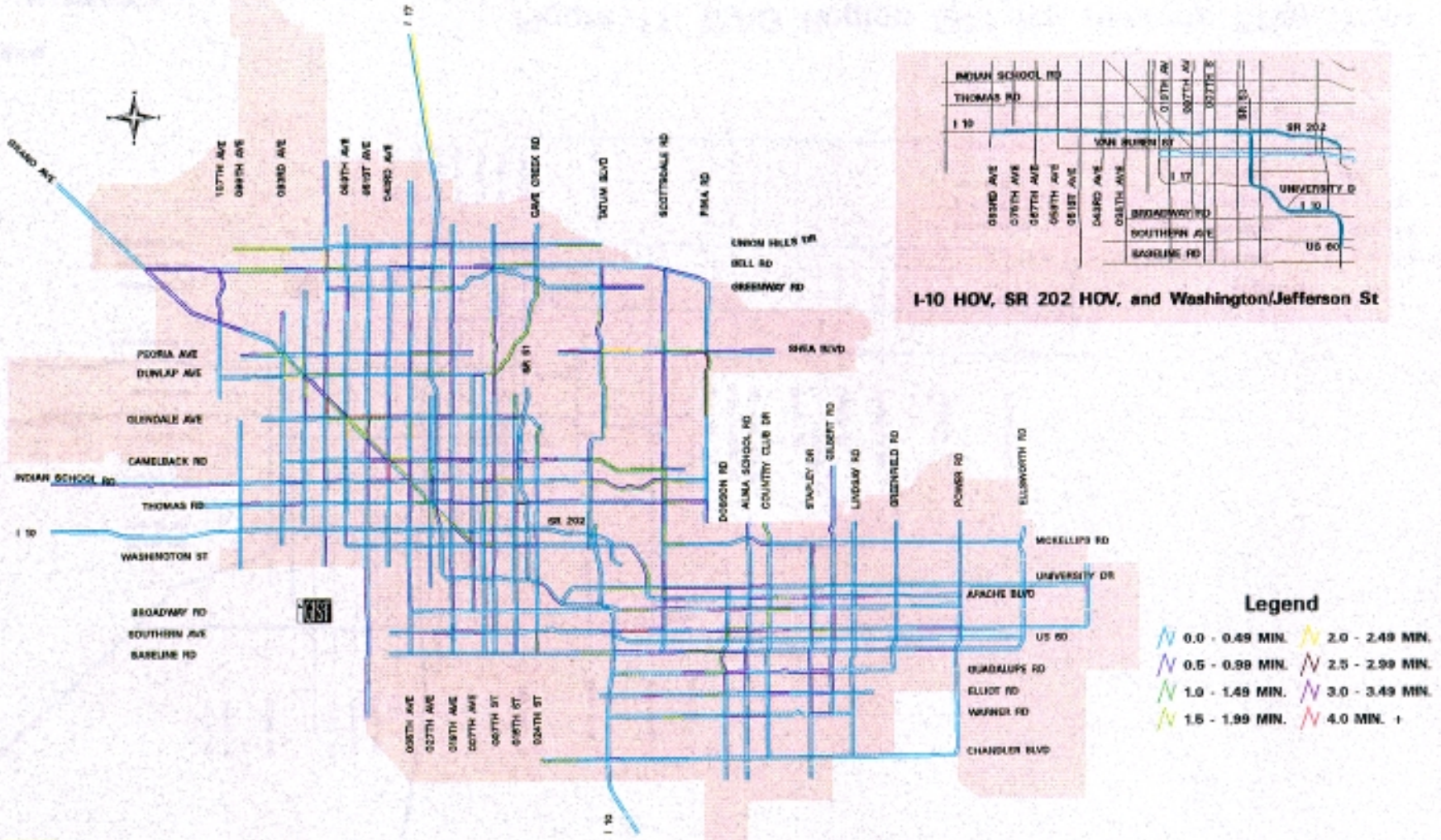


Figure 12. MAG Region PM Average Stop Delay

Table 13
Mean Recurring & Non Recurring Stop Delay by MAG Functional Class (seconds per mile)
Morning Period: 7:00 a.m.-9:00 a.m.

	Recurring Delay						Non Recurring Delay					
	Area Type						Area Type					
Functional Class	1	2	3	4	5	All	1	2	3	4	5	All
Freeway	0.00	1.21	0.95	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00
Grand Avenue	23.83	0.62	33.31	10.67	0.00	16.67	0.00	0.00	0.00	0.00	0.00	0.00
HOV Lane	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00		0.00
Minor Arterial	13.60	23.34	16.46	11.68	3.47	13.49	0.00	0.00	0.00	0.22	0.05	0.09
Principal Arterial	20.31	25.52	18.53	9.13	13.59	17.20	0.00	0.00	0.14	0.00	0.00	0.08
All	10.56	10.30	15.26	7.42	5.00	11.49	0.00	0.00	0.10	0.03	0.02	0.05

Table 14
Mean Recurring & Non Recurring Stop Delay by MAG Functional Class (seconds per mile)
Midday Period: 10:00 a.m. - 2:00 p.m.

	Recurring Delay						Non Recurring Delay					
	Area Type						Area Type					
Functional Class	1	2	6	4	5	All	1	2	3	4	5	All
Freeway	1.95	0.00	0.86	0.03	0.04	0.56	0.00	0.00	0.00	0.00	0.00	0.00
Grand Avenue	15.79	8.30	27.38	21.03	0.00	20.89	0.00	0.00	1.40	0.26	0.00	0.54
Minor Arterial	19.97	16.82	15.89	10.29	4.99	12.27	0.00	0.00	0.49	0.00	0.00	0.14
Principal Arterial	25.05	21.93	17.51	11.30	6.98	16.14	0.00	0.23	0.38	0.00	0.56	0.24
All	9.46	5.34	11.61	8.31	3.23	9.00	0.00	0.05	0.27	0.02	0.19	0.14

Table 15
Mean Recurring & Non Recurring Stop Delay by MAG Functional Class (seconds per mile)
Evening Period: 4:00 a.m. - 6:00 p.m.

	Recurring Delay						Recurring Delay					
	Area Type						Area Type					
Functional Class	1	2	3	4	5	All	1	2	3	4	5	All
Freeway	3.87	0.81	1.34	0.00	3.86	1.32	0.00	0.00	0.00	0.00	1.31	0.05
Grand Avenue	35.39	32.90	50.59	17.75	0.00	29.66	0.00	0.00	0.00	0.00	0.00	0.00
HOV Lane	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00		0.00
Minor Arterial	28.65	30.82	22.33	13.12	9.83	19.54	0.00	5.63	0.27	0.58	0.00	0.90
Principal Arterial	34.19	28.96	22.98	14.88	9.28	22.34	0.20	0.18	0.33	0.06	0.00	0.24
All	17.89	11.48	16.69	10.44	7.37	14.16	0.08	0.51	0.22	0.16	0.48	0.26

The average recurring delay on the freeway system is less than 1 second per mile during the morning and evening periods and less than 2 seconds per mile during the evening period. No recurring stop delay was reported on HOV lanes. The average recurring delay for principal arterials was 17, 16, and 22 seconds per mile during the morning, midday, and evening periods while the average stop delay on minor arterials was 13, 12, and 19 seconds per mile during the same periods. The highest average recurring delay occurred on Grand Avenue with delays of 17, 21, and 30 seconds per mile during the morning, midday, and evening peak periods respectively.

Travel Speeds by Jurisdiction and MAG Functional Class

A review was made of the average travel speeds for each segment by jurisdiction, MAG functional class, area type, and number of lanes. These speeds are shown in Tables 16, 17, and 18. The data shown in these tables have been simplified to two functional classes: freeways (which include HOV lanes) and arterials (which include principal arterials, minor arterials, and Grand Avenue).

The average travel speeds for all arterials included in the study area are 36 miles per hour during the morning and midday periods, and 34 miles per hour during the evening period. The average travel speeds for all freeways and HOV lanes included in the study area are 59 miles per hour during the morning period, 63 miles per hour during the midday period, and 58 miles per hour during the evening period.

The slowed arterial travel speeds measured occurred in area type 1 during the evening peak period. The average travel speed for arterials in this area type during the evening period was 25 miles per hour. The fastest measured arterial speed for all arterials occurred in area type 5 during the morning period. The average travel speed for all arterials in this area type during the morning period was 43 miles per hour. The slowest travel speeds for all freeways and HOV lanes was 47 miles per hour and occurred in area type 1 during the morning period. Conversely, the fastest measured travel speeds occurred in area type 5 during the midday period with an average travel speed of 66 miles per hour.

During all study periods, the slowest system travel speeds were observed in the City of Tempe, while the highest system travel speeds were observed in the City of Chandler during the morning period, and Maricopa County during the midday and evening periods. The slowest arterial travel speeds were experienced in the City of Tempe during the morning and evening periods and in Sun City during the midday period. The fastest arterial speeds were observed in the City of Surprise during all periods, with travel speeds greater than 45 miles per hour during all periods. This is not surprising since the area types for this City are 4 and 5 which correspond to the least dense population and employment.

The slowest freeway speeds occur in the City of Tempe during all periods of the day. This is not surprising since one of the slowest sections of measured travel speed on freeway segments occurred on Interstate 10 between the SR 60 (Superstition Freeway) and the SR 143 (Hohokam Freeway). The highest freeway travel speeds were experienced in the City of Chandler during the morning period and Maricopa County during the midday and evening period.

Table 16
Mean Travel Speed by Jurisdiction
Morning Period: 7:00 a.m.-9:00 a.m.

	Functional Class												
	Arterial						Freeway						
Jurisdiction	1	2	3	4	5	All	1	2	3	4	5	All	All
Apache Junction				31.3	28.2	29.7							29.7
Avondale										63.7		63.7	63.7
Chandler			41.7	38.5		40.1				66.7		66.7	49.0
County			29.6	42.2	47.0	39.6					65.6	65.6	46.1
Gilbert			41.0	44.2		42.6							42.6
Glendale			25.9	37.9		31.9							31.9
Goodyear				39.0		39.0					64.9	64.9	52.0
Mesa			34.5	38.6	48.9	40.7							40.7
Paradise Valley				30.7		30.7							30.7
Peoria				34.4		34.4							34.4
Phoenix	29.4	32.4	30.5	41.2	41.5	35.0	61.5	55.8	57.6	62.5		59.3	45.8
Scottsdale		23.5	31.6	34.1	37.3	31.6							31.6
Sun City				29.0		29.0							29.0
Surprise				54.9	55.6	55.3							55.3
Tempe		30.8	28.6	21.8		27.1		42.2	40.4	61.7		48.1	37.6
Tolleson										63.8		63.8	63.8
Youngtown				42.5		42.5							42.5
All	29.4	28.9	32.9	37.4	43.1	36.3	61.5	49.0	49.0	63.7	65.3	58.9	42.3

Table 17
Mean Travel Speed by Jurisdiction
Midday Period: 10:00 a.m. - 2:00 p.m.

	Functional Class												
	Arterial						Freeway						
Jurisdiction	1	2	3	4	5	All	1	2	3	4	5	All	All
Apache Junction				32.7	24.0	28.3							28.3
Avondale										65.7		65.7	65.7
Chandler			40.0	39.9		39.9				65.2		65.2	48.4
County			37.2	36.5	45.4	39.7					67.5	67.5	46.7
Gilbert			37.8	40.1		38.9							38.9
Glendale			31.4	35.6		33.5							33.5
Goodyear				38.4		38.4					63.3	63.3	50.8
Mesa			34.8	41.1	47.4	41.1							41.1
Paradise Valley				35.3		35.3							35.3
Peoria				31.0		31.0							31.0
Phoenix	28.1	31.8	30.9	37.0	37.1	33.0	57.1	62.1	60.0	63.6	68.3	62.2	47.6
Scottsdale		23.3	32.4	35.5	46.9	34.5							34.5
Sun City				23.9		23.9							23.9
Surprise				41.5	51.5	46.5							46.5
Tempe		31.5	29.1	26.8		29.1		60.8	61.5	62.5		61.6	45.4
Tolleson										65.4		65.4	65.4
Youngtown				34.7		34.7							34.7
All	28.1	28.8	34.2	35.3	42.0	35.5	57.1	61.4	60.7	64.5	66.4	63.3	43.3

Table 18
Mean Travel Speed by Jurisdiction
Evening Period: 4:00 p.m.-6:00 p.m.

Functional Class													
	Arterial						Freeway						
Jurisdiction	1	2	3	4	5	All	1	2	3	4	5	All	All
Apache Junction				35.4	27.1	31.3							31.3
Avondale			41.1	45.4		43.3				64.5		64.5	50.4
Chandler			33.9	36.6	39.8	36.8				65.5		65.5	44.0
County			38.5	41.3	45.3	41.7					66.5	66.5	47.9
Gilbert			38.9	32.1	36.5	35.9							35.9
Glendale			28.4	35.4		31.9							31.9
Goodyear				41.9		41.9					69.0	69.0	55.4
Guadalupe		33.2				33.2							33.2
Mesa			28.5	38.1	40.6	35.8		58.2	59.7	60.9	63.7	60.6	50.0
Paradise Valley				29.8		29.8							29.8
Peoria				29.1	23.5	26.3							26.3
Phoenix	24.7	27.6	29.2	33.2	34.7	29.9	47.0	59.6	50.6	63.5	43.2	52.8	41.3
Scottsdale		24.1	28.9	32.7	36.8	30.6							30.6
Sun City				25.9		25.9							25.9
Surprise				43.2	57.4	50.3							50.3
Tempe		25.9	26.0	18.4		23.4		43.5	39.8	60.9		48.1	35.7
Tolleson				33.5		33.5				64.1		64.1	48.8
Youngtown						39.3		39.3					39.3
All	24.7	27.7	32.6	34.8	38.0	34.1	47.0	53.8	50.1	63.2	60.6	57.7	41.1

Travel Times Between Cities

The travel time was computed between the downtowns of 9 communities and Sky Harbor International Airport. The travel routes between the cities used in the analysis were determined from Geographic Information System (GIS) by determining the minimum path based on travel time. In determining the minimum travel paths, time penalties were placed on left and right turns. These penalties used were derived from the intersection delay values for left turn movements which is discussed in Chapter V. The routes used for the analysis are included in the Appendix.

As discussed previously, data collection was not conducted on all routes during the morning and midday periods. In order to develop the point-to-point travel time tables for the morning and midday periods it was necessary to estimate the travel time for routes not included in the data collection during these periods. To do this, average travel times per mile were computed based on MAG functional class for data which was collected during these periods. An average travel time (on a per mile basis) was then assigned to each roadway segment not included in the data collection based on its functional class and length.

The results of the point-to-point travel times are summarized in Table 19, 20, and 21. The shortest trip occurs between Sun city and Peoria. Trips between these two cities require between 6.0 and 7.5 minutes. Conversely, the longest trip occurs between Gilbert and Sun City. This trip requires nearly 62 minutes during the morning and evening periods and nearly 57 minutes during the midday period.

As shown in the tables, there is generally not a significant difference in the travel time depending on the direction of travel between cities. For example, the travel time from Tempe to Phoenix during the morning period is 15.8 minutes, while the trip from Phoenix to Tempe is 15.6 minutes.

Travel Times from Central Phoenix and Sky Harbor Airport

To obtain a comparative picture of travel times along different routes, maps were developed depicting travel time contour lines of equal travel time from a specified reference point. For this study, contour line maps were developed for two reference points, central Phoenix and Sky Harbor International Airport. These locations are consistent with the locations used in the 1986 travel speed study. Contour lines were mapped for travel times of ten, twenty, and thirty minutes for all three survey periods.

Central Phoenix Travel Times

The intersection of Central Avenue and Van Buren was selected to represent Central Phoenix. This reference point is consistent with the reference point used in the 1986 study. The resulting travel speed contour maps using this reference are shown in Figures 13, 14, and 15 for the morning, midday, and evening periods, respectively.

Table 19
AM Place-to-Place Travel Time Matrix
Destination

Origin	Phoenix	Tempe	Scottsdale	Glendale	Sun City	Peoria	Gilbert	Chandler	Mesa	Sky Harbor
Phoenix	0.00	15.6	24.4	19.1	33.9	27.5	34.7	28.8	27.6	11.2
Tempe	15.8	0.0	15.8	28.8	42.9	36.2	25.0	23.1	12.0	9.7
Scottsdale	24.1	15.6	0.0	31.1	45.9	39.8	36.6	37.4	22.8	21.6
Glendale	18.6	29.3	33.4	0.0	14.8	8.7	48.3	42.5	41.2	25.1
Sun City	32.0	42.7	47.4	13.4	0.0	6.0	61.7	55.9	54.6	38.5
Peoria	26.0	35.8	41.4	7.4	6.1	0.0	54.9	49.0	47.8	31.6
Gilbert	34.4	25.5	37.2	47.4	61.4	54.7	0.0	10.0	14.9	29.3
Chandler	35.0	26.1	37.7	48.0	62.0	55.3	9.1	0.0	14.0	29.9
Mesa	27.8	12.0	25.0	40.8	54.8	48.1	14.9	14.6	0.0	22.3
Sky Harbor	11.2	9.7	22.3	24.5	38.6	31.9	29.5	23.6	22.5	0.0

Table 20
AM Place-to-Place Travel Time Matrix
Destination

Origin	Phoenix	Tempe	Scottsdale	Glendale	Sun City	Peoria	Gilbert	Chandler	Mesa	Sky Harbor
Phoenix	0.0	16.2	23.3	17.0	32.5	25.0	29.4	29.7	24.3	10.9
Tempe	15.9	0.0	16.5	27.3	42.8	35.3	23.1	24.1	11.7	9.1
Scottsdale	23.5	15.4	0.00	34.9	50.4	42.9	33.7	35.8	22.7	21.9
Glendale	17.7	28.1	34.6	0.0	15.5	8.0	42.0	42.3	36.9	23.6
Sun City	32.6	42.8	50.0	14.9	0.0	6.5	56.6	56.9	51.6	38.3
Peoria	26.1	35.5	43.3	8.4	7.5	0.0	49.3	49.6	44.3	31.0
Gilbert	29.2	21.7	33.4	41.1	56.6	49.2	0.0	10.1	14.1	23.8
Chandler	30.6	23.3	35.0	42.5	58.0	50.5	9.5	0.0	14.3	25.1
Mesa	24.6	11.7	23.4	36.6	52.1	44.6	14.1	14.8	0.0	19.2
Sky Harbor	11.4	10.2	20.0	23.3	38.8	31.3	24.4	24.7	19.4	0.0

Table 21
AM Place-to-Place Travel Time Matrix
Destination

Origin	Phoenix	Tempe	Scottsdale	Glendale	Sun City	Peoria	Gilbert	Chandler	Mesa	Sky Harbor
Phoenix	0.0	19.6	26.8	22.0	36.3	29.5	33.8	32.8	27.2	11.1
Tempe	16.1	0.0	18.4	31.4	45.0	37.7	25.0	25.5	12.7	9.1
Scottsdale	27.0	16.8	0.0	40.7	54.9	47.5	37.9	38.3	24.4	23.7
Glendale	21.3	31.2	38.3	0.0	14.3	7.5	47.1	46.0	40.5	24.4
Sun City	35.7	45.7	53.9	16.0	0.0	7.0	61.6	60.5	55.0	38.9
Peoria	27.9	37.8	46.0	9.0	6.8	0.0	53.7	52.6	47.1	31.0
Gilbert	32.0	25.9	38.6	48.1	61.7	54.4	0.0	9.9	16.1	26.8
Chandler	30.4	24.6	37.3	46.4	60.1	52.7	9.9	0.0	13.4	25.2
Mesa	27.3	11.5	23.9	43.4	57.0	49.7	17.6	16.5	0.0	21.2
Sky Harbor	11.4	13.0	22.7	27.4	41.1	33.7	29.1	28.0	22.5	0.0

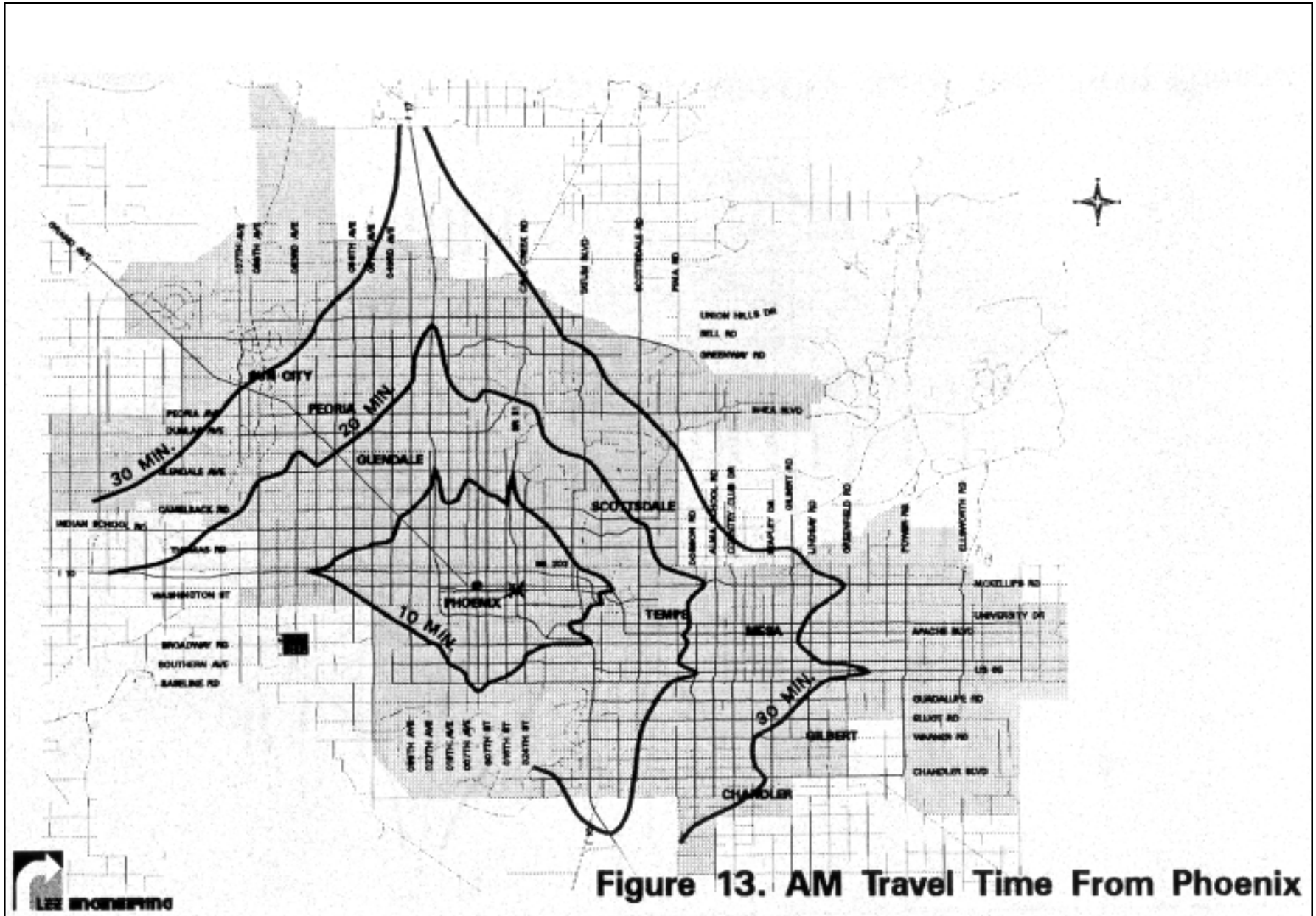


Figure 13. AM Travel Time From Phoenix

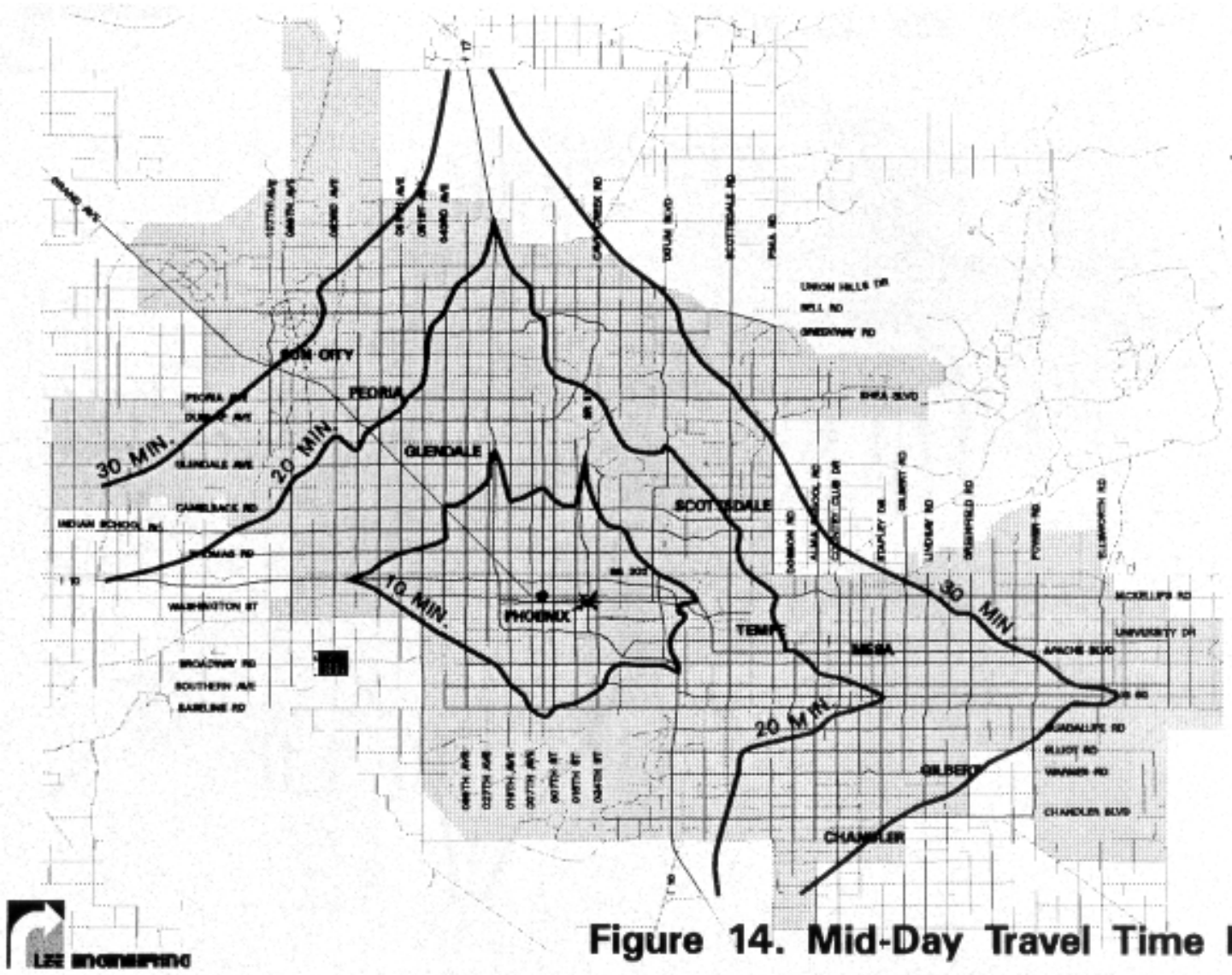


Figure 14. Mid-Day Travel Time From Phoenix

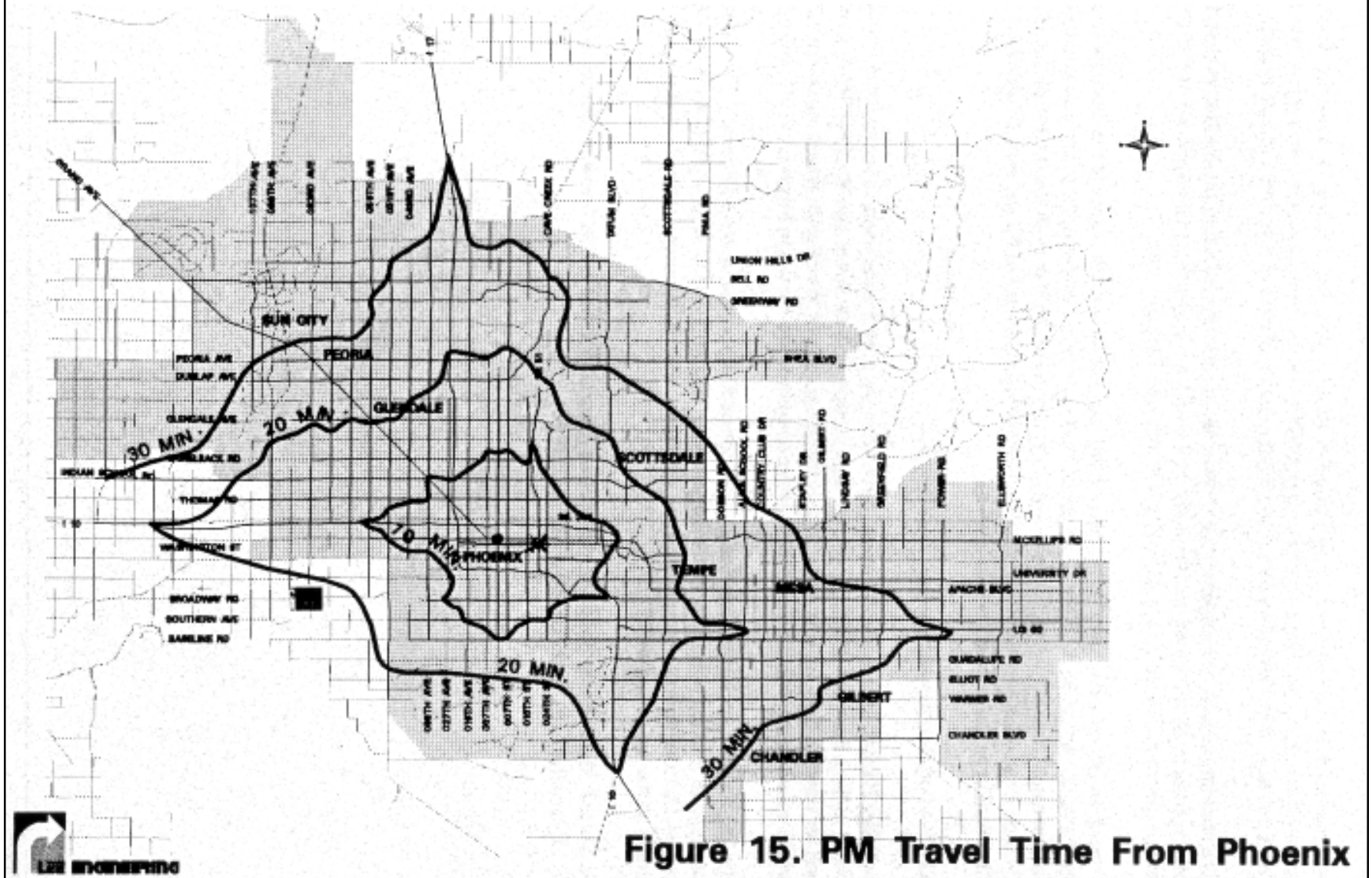


Figure 15. PM Travel Time From Phoenix

As discussed in the section on point-to-point travel times, travel times for roadway segments not surveyed during the morning and midday periods were approximated based on average travel speeds (on a per mile basis) based on data collected for streets of similar functional classification.

The contour lines for the midday period cover the largest area. During the midday period, the thirty minute contour lines fall outside the study area along the freeways in all directions except to the east. In this direction, the contour line nearly falls outside the study area.

During all periods, the extreme reaches of the contour lines are located on the freeway segments of Interstate 10, Interstate 17, US 60 (Superstition Freeway). For example, to the east one can drive to the intersection of US 60 and Stapley Drive during the midday period, the intersection of US 60 and Dobson Road during the morning period, and the intersection of US 60 and Alma School Road during the evening period in twenty minutes time.

Sky Harbor International Airport Travel Times

For Sky Harbor International Airport, two reference points were used to represent the airport. For travel to/from the west of the airport, the intersection of 24th Street and Buckeye Road was selected and for travel to/from the east of the airport the intersection of Washington Street and 40th Street. The travel speed contour maps using these reference points are shown in Figures 16, 17, and 18.

Similar trends appear for Sky Harbor International Airport as central Phoenix. The contour lines during the midday period cover the largest area, primarily due to higher travel speeds. During this period, the contour lines extend nearly to the study limits to the north and east, and beyond the study limits to the south and west.

In general, the extreme points on the contour lines are located on the freeway system to the north (I-17), south (I-10), east (US 60), and west (I-10).

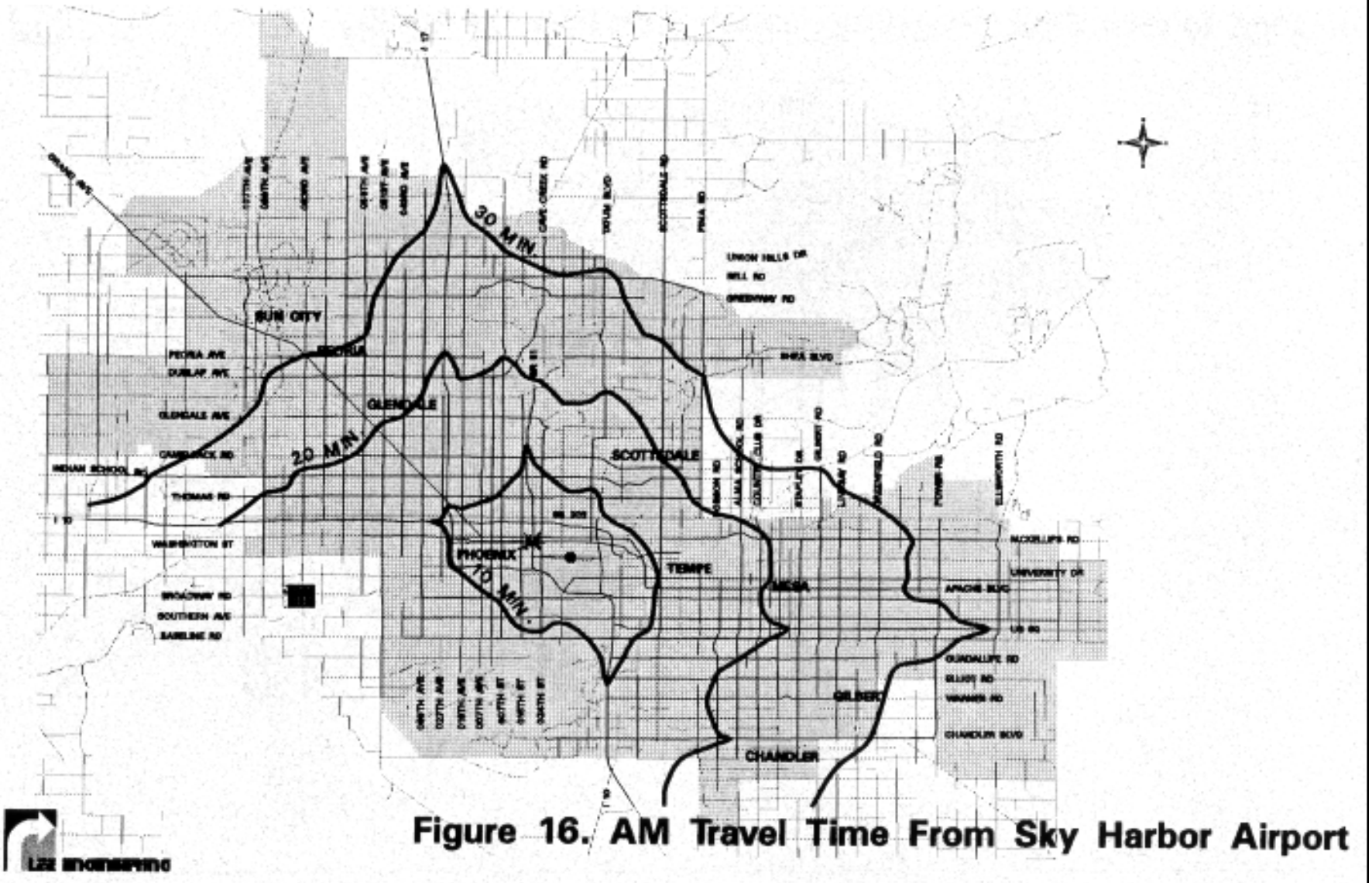


Figure 16. AM Travel Time From Sky Harbor Airport

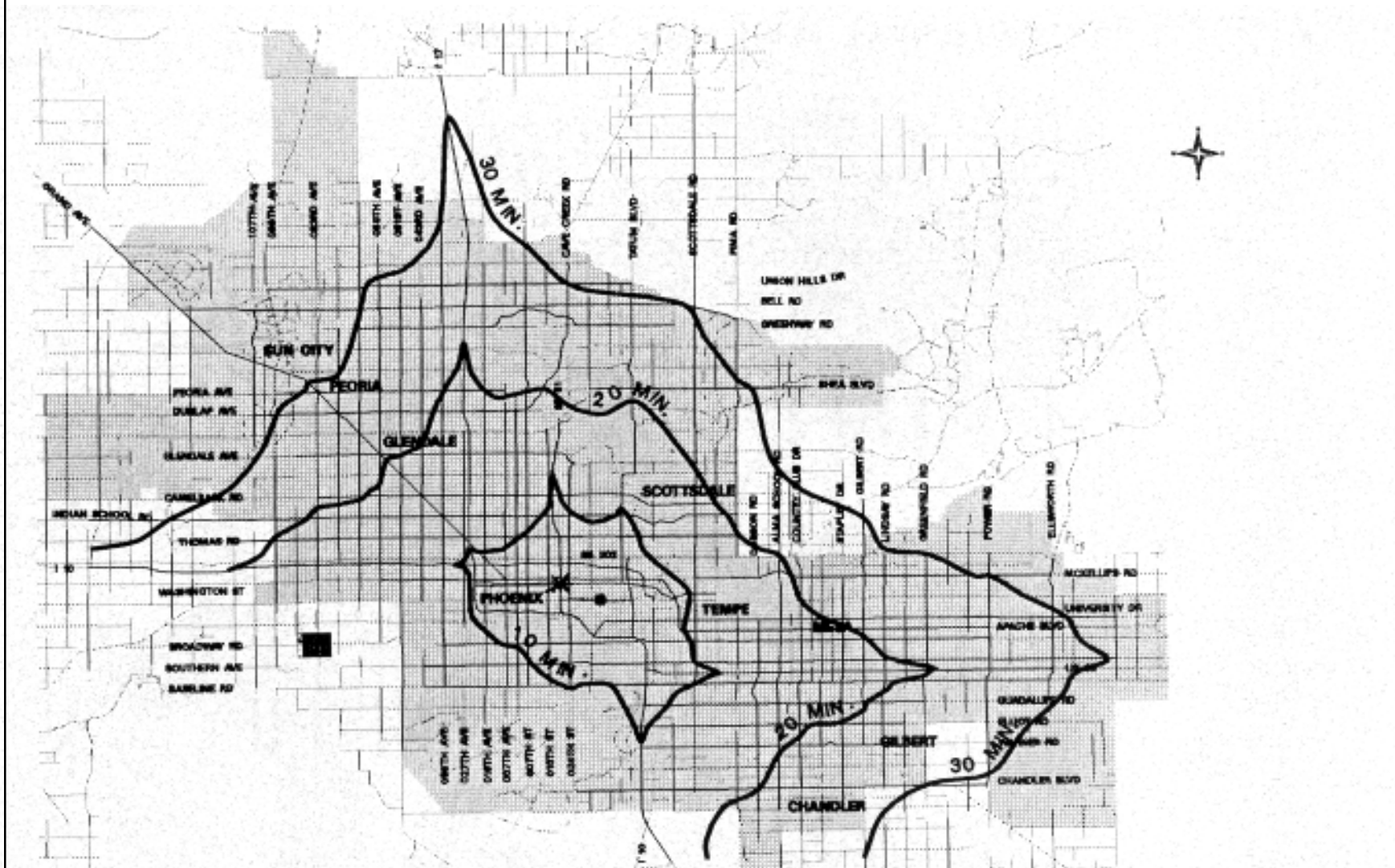


Figure 17. Mid-Day Travel Time From Sky Harbor Airport

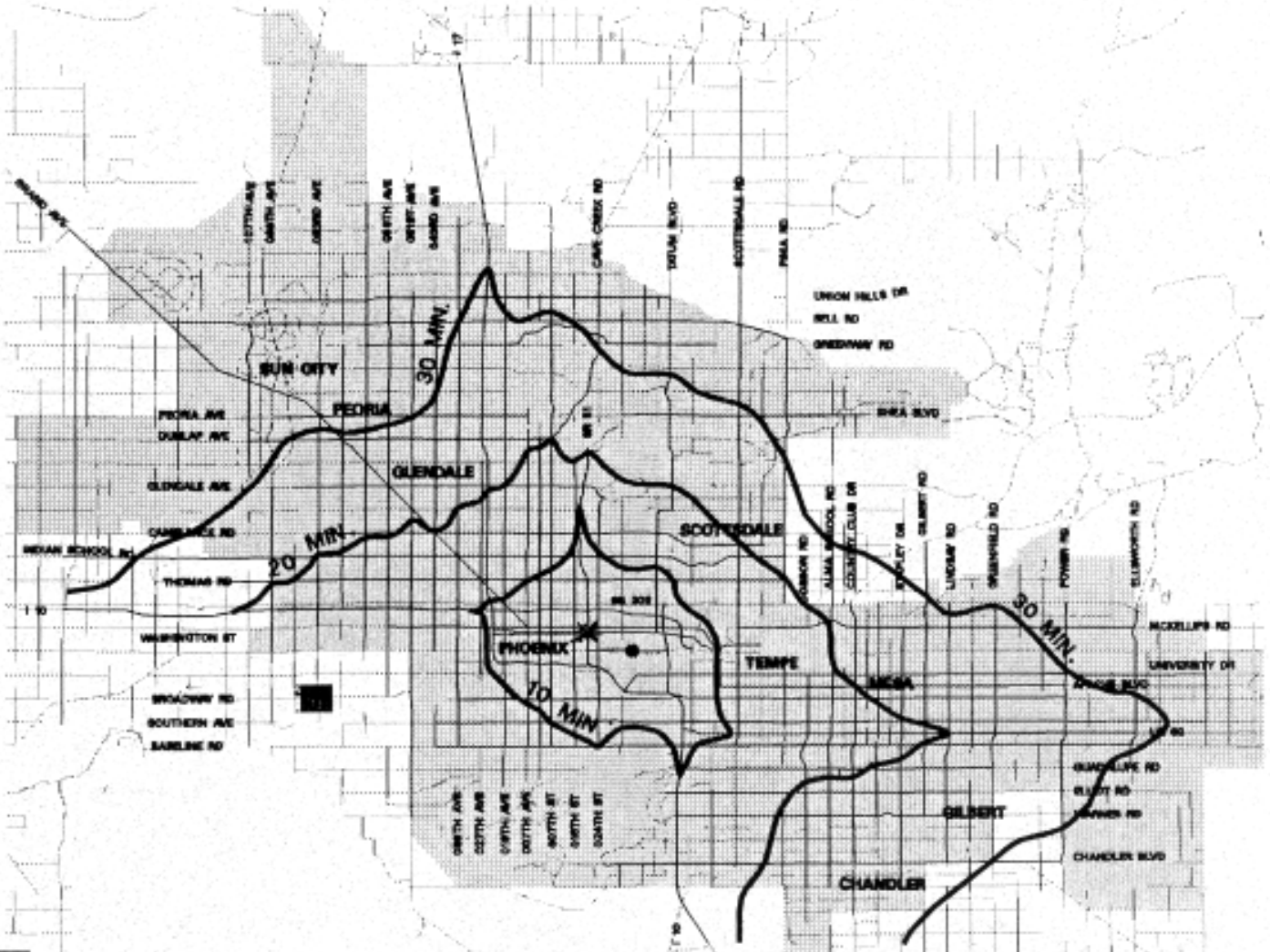


Figure 18. PM Travel Time From Sky Harbor Airport

IV. INTERSECTION DELAY

The purpose of the intersection delay data is to help explain the relationship between volume and capacity at intersections and their effect on delay. The MAG planning model uses link v/c to estimate delay due to congestion during the assignment portion of a model run. However, there is justification to move towards an intersection delay-based algorithm. While this capability has not yet been implemented, this data collection effort will provide a database which can be used once implemented.

Based on the results of field testing, Lee Engineering used a path trace method using video tracking to collect delay data. Because of the accuracy of the resulting data, this method was chosen over the interval sampling method, even though the data reduction was more time-consuming. The results of this method provide the needed accuracy for development of an intersection delay model.

Description of Measured Data

Travel Time Delay (TTD) is the difference between the time a vehicle passes a point downstream of the intersection where it has regained normal speed and the time it would have passed that point had it been able to continue at its approach speed.

Stopped-Time Delay (STD) is the time a vehicle is substantially standing still while waiting in line in the approach to a signalized intersection.

Figure 19 further illustrate the values collected for this study. There are two travel paths shown on the figure. The actual path of the subject vehicle (test vehicle) is shown as V_p. A path of a vehicle which experiences no slowdown due to intersection delay is shown by the path V_p. For the purposes of this delay study, raw times were measured of a sample of vehicles in the traffic stream passing $T_■$ (upstream data point) and T_i (the stop bar of the intersection). Once the vehicle passes the upstream camera location, $T_{■9}$ it continues at the free flow speed until it begins to decelerate at point T_{bd}. It continues decelerating until it comes to a stop at point T_{ed}. The test vehicle remains at the same location until it is time to start accelerating again at point T_{ba}. It again regains free flow travel speed at point T_{ea}.

The vehicle passes the stop bar of the intersection either before or after reaching free flow travel speed. Figure 19 shows the vehicle reaching the intersection before attaining free flow speed, but the intersection could be reached after point T_{ea}.

For planning purposes, the total delay encountered by the vehicle is T_{td}. This is the time difference between when the test vehicle passes the intersection (T_i) and when a free flow vehicle would have passed through the intersection (T_i). For this study, T_{ff} was obtained by taking the distance between T_i and $T_■$ and dividing by the speed limit.

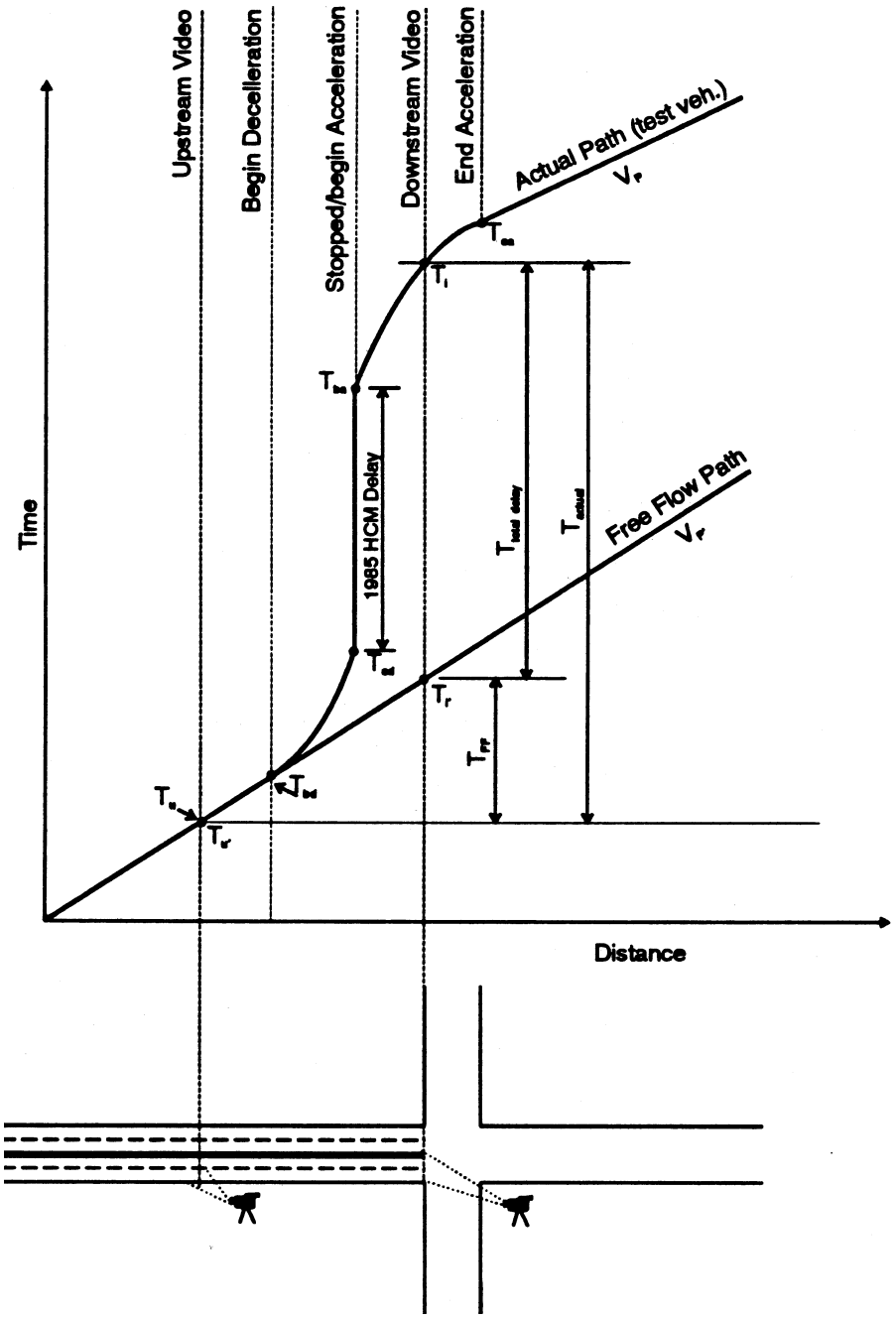


Figure 19: Illustration of Delay Values

Using the 1985 HCM Methodology

In the 1985 Highway Capacity Manual, it is recommended that the delay be reported as stopped time delay. This is the time in which a vehicle is considered to be stopped. In Figure 1, this is depicted as the time between T_{ed} and T_{ba}. Other research has indicated that TTD is calculated by multiplying STD by a factor of 1.3.

For planning purposes, the value of interest is the total time delay (TTD). In transportation models, vehicles are considered to be traveling at the average running speed until congestion starts to build. This departure from running speed to a congested situation is the definition of TTD. While it is certain that TTD is greater than STD, it is not certain that it is greater by a factor of 1.3 and further research into this is warranted. However, this study has collected TTD directly.

DATA COLLECTION

Methodology

Intersections were selected based on three variables: area type, left turn phasing, and functional class. Also, intersections that were known to be congested were targeted for data collection.

Area Type	Left Turn Phasing	Roadway Class
Urban Core	Permissive	Minor Arterial
Urban	Permissive/Protected	Major Arterial
Suburban	Protected	Urban Collector

The volume to capacity (v/c) ratio is recognized as an important factor in the study. However, it is not possible to select intersection approaches based on predetermined levels of v/c ratios. Therefore, it is assumed that a range of v/c rations will be collected during the course of the study. Once the v/c ratios have been calculated for each 15 minute interval, then the effect that v/c has on intersection delay can be determined.

Collecting data at one intersection required nine people. Four people monitored traffic at the stop bars. They were responsible for setting up and synchronizing a video camera. They also conducted a turning movement count (TMC) for one approach. While conducting the TMC, the observer will also tracked the green time of the signal. The TMC count and phasing were collected on a single Tandy 102 portable computer.

Four other people monitored traffic upstream of the intersection at a location near the end of the longest likely queue. These four people were responsible for setting up and synchronizing a video camera as well as count traffic. Since they counted only one traffic stream, they used stopwatches and mechanical traffic counters to record volumes.

The final person made note of the lane arrangements and measured the distance from each stop bar to the location the upstream data collector was filming for that approach.

Figure 20 illustrates the location and function of each data collector.

Field Survey

Phase I traffic data were collected (filmed and counted) at the following intersections:

Intersection
Southern Ave/McClintock Dr.
Glendale Ave/Central Ave
Warner Rd/Arizona Ave

Preliminary analysis was performed on these three intersections. After examining these results, the data collection methodology was determined to be valid. The remaining data were collected at the following locations:

Intersection
McDowell Rd/Central Ave.
McDowell Rd/24th St.
Camelback Rd/44th St.
Northern Ave/7th St.
Thunderbird Rd/40th St.
University Dr/Priest Dr.
Indian School Rd/Hayden Rd
Bell Rd/32nd St.
Union Hills Dr/7th Ave
Greenway Ave/35th Ave
Cactus Rd/Scottsdale Rd
McDonald Dr/Hayden Rd

Traffic was observed for one hour during the evening peak (4:30 p.m.-5:30 p.m.) for all the intersection except three. Those three were observed for one hour during the morning peak (7:30 a.m.-8:30 a.m.)

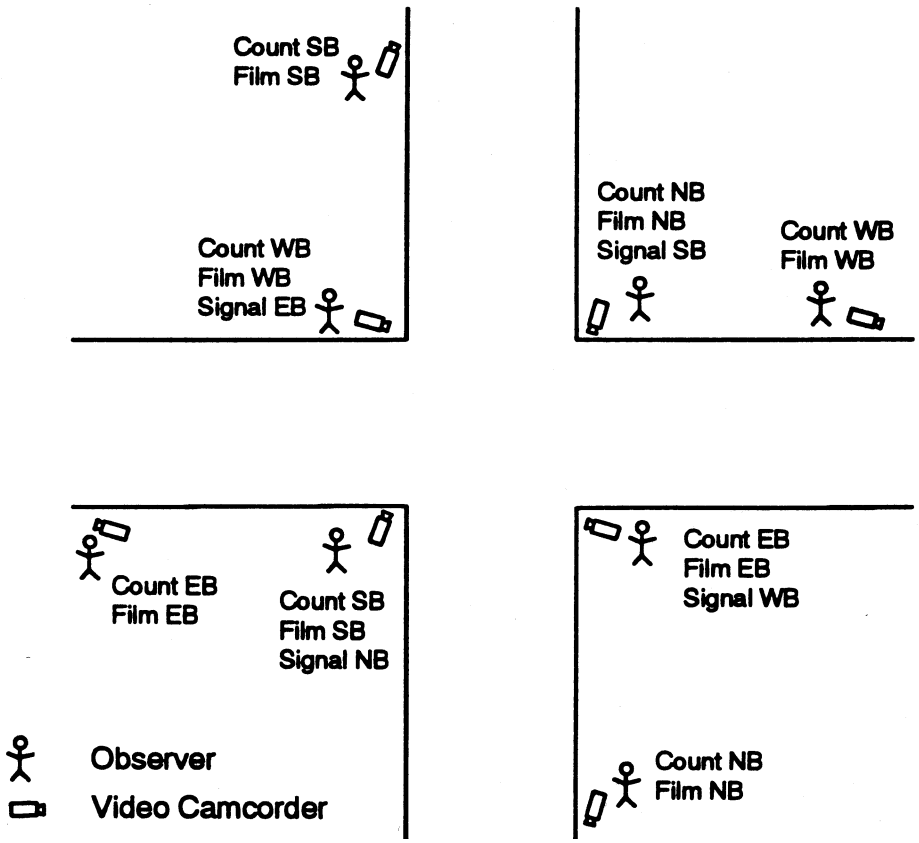


Figure 20 Intersection Delay Collection Team

Three types of data came from this method: videotape, upstream data sheets, downstream Tandy files.

Videotape
Each tape was transferred to a master tape while simultaneously imprinting it with a time stamp. The time stamp is accurate to the hundredth of a second. Following this, a data collector viewed both tapes while running a computer program on a PC. The program allowed the data collector to input the upstream and downstream times of vehicles and whether or not the vehicle turned left. These times were subsequently written into a file for later processing. Error checking routines within the program minimized incorrect data input.

It was noted during the timestamping that the time according to the timestamp did not always correlate to real time during the course of an hour. There are several possible explanations for this problem: VCR playback speed not the same as camcorder recording speed, battery weardown, and temperature

effects on videotape. Over the course of an hour, times may have separated by as much as 30 seconds. An assumption was made that this change is linear in nature. Therefore, a computer program was written to take the previous delay data file and adjust the times throughout the hour.

For example: Suppose that when the data collector said it was 5:30:00, the timestamp said it was 5:30:20. A BASIC program used a corrective equation to adjust times such that vehicles near the end of the hour had 20 seconds added to their times, vehicles at the beginning of the hour had 0 seconds added to their times, and vehicles in between had some number between 0 and 20 seconds added to their times. These times are referred to as "adjusted" times.

These adjusted upstream and downstream times represent the total time for a vehicle to transverse the study area. Delay is calculated by subtracting the time it would take the vehicle to transverse the study area unimpeded by signals or other vehicles. This free flow time was based on the speed limit. Another BASIC program was written to subtract out the free flow time and output the final delay file (described later).

Data Collection Sheets

The upstream data collectors collected traffic volumes at five minute intervals. The volumes were recorded on a sheet of paper. The data from the paper was transferred to a PC file back in the office.

Tandy Volume Files

The downstream data collectors used a modified version of Lee Engineering's COUNT program to collect traffic and signal information. Each data collector observed vehicles on one approach and the signals on the opposite approach. Approach volumes were separated into left, through, and right turning vehicles in five-minute intervals. The two files (signal and volume) were downloaded to a PC for further analysis.

Missing Data

Due to various circumstances some approaches are missing data. A typical cause of lost data were malfunctioning video cameras.

Data Processing

Once all of the data were downloaded, transcribed, and adjusted, several larger data files were created for subsequent input into SAS A sample of each file is given in the appendix.

The first file (FINAL.DEL) is the combined adjusted delay file. It contains the time the vehicle passed the upsteam location, the time the vehicle passed the downstream location, the total time difference, the stopped time delay, and a code indicating whether or not the vehicle turned.

The second file (FINAL.SIG) is the signal information file. This file contains information on signal timing such as green times, cycle length, left-turn phasing, facility type, area type, etc. for each approach-interval.

The third file (FINAL.VOL) is the volume information file. Data elements in this file include upstream volumes, downstream volumes, saturation, and saturation flow rates.

A SAS program (see appendix) reads in these three files and outputs the data tables shown on pages

58-59. The table summarize the results of the analysis. An explanation of each data element is also given in the appendix.

Table 22 lists the mean total delay, the standard deviation, and the sample size for each interval on each through-right approach of the fifteen intersections. Mean stopped delays range from 6.5 seconds to 217.7 seconds.

Table 23 lists the mean total delay, the standard deviation, and the sample size for each interval on each left turn approach of the fifteen intersections. Mean stopped delays range from 6.2 seconds to 248.5 seconds.

Figures 21-25 show comparisons between volume-to-capacity ratios and mean approach delay (in seconds). Figure 21 plots the delays of all approach types (left turn and through-right approaches) versus theoretical volume-to-capacity ratio. Figure 22 is a comparison of the theoretical v/c for through-right approaches and mean delay. Similarly, figure 23 plots the theoretical v/c for left turn approaches against mean delay. Finally, figures 24 and 25 plot the v/c values with respect to actual volume-to-capacity ratios. Theoretical and actual volume-to-capacity ratios are defined in the section of the Appendix called "Description of Variables in the Data Summary Table."

Table 22
Delay Summary Table
Through-Right Turning Vehicles

Location	Direction	Interval											
		1			2			3			4		
		Mean	Std Dev	n	Mean	StdDev	n	Mean	Std Dev	n	Mean	Std Dev	n
Bell/32nd St	eb	27.7	27.4	79	28.5	23.8	115	26.1	25.0	79	28	19.5	78
	nb	39.1	28.5	63	37.2	25.7	52	21.9	23.2	59	28	25.6	62
	sb	30.0	24.8	76	37.6	27.5	68	41.1	26.9	81	31.8	27.4	75
bel32	wb	41.2	18.9	93	43.3	27.2	74	24.6	23.3	81	39.2	22.9	84
Cactus/Tatum	eb	21.7	15.8	70	24.6	18.6	80	28.4	19.7	76	28.3	22	83
	nb	41.6	27.8	77	25.5	25.3	93	28.0	24.6	94	22.8	21.1	96
	sb	50.5	22.4	78	39.1	18.8	84	46.1	16.5	91	47	18.3	84
cacta	wb	42.1	23.5	91	41.9	24.3	75	40.9	21.3	89	40.7	20.7	86
Camelback/44th St	eb	43.4	34.1	84	50.6	24.9	72	47.9	30.6	67	111.3	41.1	94
	nb	28.8	24.4	94	29.5	25.1	90	35.0	19.8	96	125	47.3	93
cam44	sb	41.8	30.5	93	31.7	30.3	85	23.5	25.8	83	41.2	30.5	95
	wb	36.7	29.6	78	45.0	30.2	88	39.1	31.4	74	48.2	28.2	72
Glendale/Central	eb	9.2	19.1	101	7.3	16.2	99	10.9	38.7	97	16.1	21.9	96
	nb	18.7	19.3	117	61.9	20.1	80	38.0	18.8	72	75.5	21.7	95
gle00	sb	8.8	9.5	89	13.6	37.2	87	9.4	20.1	89	6.5	12.3	98
	wb	16.7	21.3	98	39.4	24.6	103	24.5	25.3	98	84.3	22.5	103
Greenway/35th Ave	eb	.	.	.	.	.	.	.	.	.	.	.	.
	nb	17.4	17.5	58	19.4	20.7	52	12.3	14.4	86	14.8	21.1	78
gre35	sb	49.4	31.7	78	44.6	36.3	89	18.4	17.4	89	21.2	17.7	80
	wb	.	.	.	16.9	15.6	85	13.9	13.0	84	11.3	11.6	76
Indian School/Hayden	eb	54.8	29.0	89	57.6	28.4	89	78.3	71.2	92	89.4	33.9	90
	nb	50.3	24.5	97	54.5	30.7	121	65.8	34.7	101	80.7	35	98
indha	sb	31.4	17.0	93	35.5	23.7	94	34.3	20.1	87	39.1	21.8	81
	wb	68.6	43.0	64	50.6	35.3	89	89.5	45.5	78	79.1	41.9	90
McDowell/Central	eb	27.1	21.4	95	25.3	20.2	89	27.4	16.5	100	24.8	19.5	94
	nb	28.4	21.9	83	27.1	21.2	90	38.6	23.0	82	41.4	25.5	93
mcdoo	sb	26.3	22.8	73	29.0	20.1	71	39.4	22.0	76	32.8	23	80
	wb	31.1	18.3	99	36.9	15.1	100	53.8	31.0	100	45.8	19.7	100
McDowell/24th St	eb	29.3	20.5	23	25.3	23.4	73	30.0	22.7	49	34.7	29.2	57
	nb	.	.	.	.	.	.	.	.	.	.	.	.
mcd24	sb	20.8	21.1	72	9.9	16.7	62	17.2	21.3	59	18	25.5	65
	wb	25.8	22.9	68	20.0	21.4	73	12.6	19.6	69	22.3	21.5	74
McDonald/Hayden	eb	74.8	43.5	51	.	.	.	168.3	34.7	40	217.7	56.4	36
	nb	49.2	23.2	92	38.3	29.3	92	30.4	23.4	93	46.6	22.5	89
mcdha	sb	.	.	.	166.8	43.0	136	174.1	25.9	84	76	36.1	87
	wb	83.8	66.6	75	194.8	34.9	77	54.2	34.6	76	48	30.1	51
Northern/7th St	eb	8.9	12.0	73	10.4	11.0	73	27.2	157.0	80	12.9	13.9	86
	nb	80.0	31.6	77	90.7	17.0	74	98.4	18.6	79	80.5	23.1	75
nor07	sb	22.3	19.9	74	14.1	15.3	67	16.6	19.5	77	13.7	16.8	80
	wb	15.5	13.0	64	22.5	14.0	59	31.9	16.6	57	46.4	23	28
Southern/McClintock	eb	46.4	28.1	84	74.4	38.4	89	91.1	31.2	95	82.9	23.3	13
	nb	33.6	21.4	86	45.6	25.0	85	31.6	16.8	91	34.3	16.8	98
soumc	sb	28.0	14.3	98	35.8	21.1	98	41.8	21.2	83	64.6	36.8	60
	wb	23.4	25.5	87	33.0	33.7	87	26.8	30.6	79	24	23.5	78
Thunderbird/40th St	eb	.	.	.	.	.	.	.	.	.	.	.	.
	nb	13.3	15.1	89	17.8	15.3	92	19.8	15.2	82	23.8	15.2	85
thu40	sb	12.7	13.4	114	24.2	62.0	73	11.8	12.6	72	18.1	15.5	77
	wb	10.8	15.7	57	20.1	23.9	69	13.2	17.3	61	12.3	16.1	56
Union Hills/7th St	eb	23.4	9.9	55	24.2	15.3	94	22.4	10.0	83	20.4	9.8	88
	nb	.	.	.	.	.	.	.	.	.	.	.	.
uni07	sb	18.8	19.6	48	21.5	17.2	65	19.0	16.6	100	17.3	15.7	57
	wb	13.5	13.6	76	10.1	10.3	84	15.2	15.0	77	12.9	10	92
University/Priest	eb	.	.	.	.	.	.	.	.	.	.	.	.
	nb	22.3	25.3	86	22.0	22.4	93	30.1	27.4	90	28.3	31.3	92
unipr	sb	31.8	22.3	82	37.7	16.3	87	26.3	18.5	86	25.9	17.8	89
	wb	20.3	21.7	58	17.2	20.6	90	25.4	22.9	87	28.3	22.6	90
Warner/Arizona Ave	eb	26.3	29.3	90	28.5	21.4	96	25.9	21.2	98	24.3	19.3	100
	nb	18.9	16.3	99	21.8	17.9	96	27.7	10.6	97	28.6	16.4	98
warar	sb	18.5	14.6	101	18.7	18.4	96	14.5	17.8	96	21.6	19.4	101
	wb	26.0	21.5	93	32.1	24.1	92	27.6	21.4	94	32.4	25.8	91

Notes: Mean=Mean Travel Time Delay (seconds/vehicle)
Std Dev = Standard Deviation
n = Sample size
. No Data Available

Table 23
Delay Summary Table
Left Turning Vehicles

Location	Direction	Interval											
		1			2			3			4		
		Mean	Std Dev	n	Mean	Std Dev	n	Mean	Std Dev	n	Mean	Std Dev	n
Bell/32nd St	eb	34.4	25.1	21	21.6	18.1	36	14.7	7.4	24	23.7	15.4	23
	nb	39.4	30.3	37	19.9	17.6	47	19.0	18.3	41	23.7	15.9	38
	sb	20.3	15.4	26	27.9	22.5	35	35.8	30.6	23	18.2	13.0	25
	wb	54.7	22.5	38	36.7	23.5	24	28.8	20.3	21	33.0	26.3	15
Cactus/Tatum	eb	20.4	19.3	27	17.9	17.3	19	17.4	13.1	25	23.7	19.2	13
	nb	45.7	26.0	22	65.2	42.6	6	6.2	4.5	5	.	.	.
	sb	44.3	24.1	19	34.8	22.5	16	32.7	15.4	10	29.9	15.4	16
	wb	35.3	18.9	7	41.6	15.5	27	30.3	12.0	10	36.2	10.6	13
Camelback/44th St	eb	39.4	33.3	17	67.2	29.8	29	54.1	22.5	34	124.8	8.8	6
	nb	48.6	33.6	7	24.2	16.7	11	44.3	31.3	6	46.5	21.9	8
	sb	55.4	29.2	7	38.2	26.8	15	41.9	30.3	17	59.2	31.0	5
	wb	34.1	21.0	22	56.2	22.0	22	40.7	19.5	27	75.0	26.5	30
Glendale/Central	eb	89.0	.	1	116.0	.	1	102.3	92.6	3	48.3	18.4	4
	nb	26.1	16.4	14	61.1	34.5	18	66.5	24.1	28	102.1	27.3	7
	sb	113.2	58.0	11	114.6	66.4	13	153.1	36.3	11	248.5	48.8	2
	wb	48.0	24.0	2	27.0	11.4	3	19.0	.	1	46.5	33.2	2
Greenway/35th Ave	eb	.	.	.	.	.	.	.	.	.	.	.	.
	nb	28.3	22.0	43	57.3	48.1	46	19.5	19.8	15	19.4	24.7	22
	sb	25.3	15.9	11	47.3	24.0	12	28.7	24.9	12	25.8	19.7	24
	wb	.	.	.	28.7	25.5	15	28.5	37.6	18	16.8	17.1	25
Indian School/Hayden	eb	81.3	27.1	13	63.9	10.2	10	85.9	28.4	11	126.0	40.0	9
	nb	148.0	.	1	50.0	8.5	2	107.4	39.3	10	106.7	39.3	11
	sb	23.9	28.9	7	48.2	35.9	6	47.0	29.2	11	55.1	25.7	17
	wb	110.5	44.0	35	30.6	10.6	10	93.4	57.0	25	173.6	5.5	10
McDowell/Central	eb	.	.	.	.	.	.	.	.	.	.	.	.
	nb	27.0	22.7	16	28.0	14.3	10	36.3	22.9	18	41.4	24.2	7
	sb	40.2	17.2	27	35.7	32.1	30	68.6	46.2	24	109.1	29.8	20
	wb	48.0	.	1	.	.	.	.	.	.	.	.	.
McDowell/24th St	eb	27.7	20.7	10	19.8	21.1	27	25.5	20.2	51	40.4	28.0	43
	nb	.	.	.	.	.	.	.	.	.	.	.	.
	sb	30.4	24.7	28	11.0	15.5	38	24.6	24.7	41	23.2	23.8	35
	wb	24.9	23.4	32	18.0	22.0	27	20.0	19.7	31	26.3	21.0	27
McDonald/Hayden	eb	131.6	52.2	45	.	.	.	176.0	34.8	52	218.5	47.1	55
	nb	41.8	27.3	8	49.4	25.0	8	50.8	15.3	6	35.3	22.3	11
	sb	.	.	.	150.5	49.8	39	173.7	22.3	18	129.9	83.0	23
	wb	162.4	91.3	25	198.1	37.1	24	44.7	32.4	23	64.0	34.0	47
Northern/7th St	eb	19.8	20.6	27	17.3	16.8	27	30.0	26.1	21	12.9	14.1	14
	nb	84.4	39.0	23	99.8	17.7	26	92.1	20.0	21	75.8	34.1	25
	sb	21.6	29.1	26	19.5	29.3	33	14.2	13.8	23	10.8	11.3	20
	wb	17.9	14.8	36	24.1	12.1	41	31.5	17.5	41	46.3	16.0	40
Southern/McClintock	eb	80.2	27.5	6	75.4	30.6	7	77.2	25.7	6	.	.	.
	nb	58.3	32.8	14	44.7	26.6	15	47.3	31.3	12	71.5	35.2	4
	sb	88.3	18.9	4	48.7	28.6	3	92.5	2.1	2	81.5	32.1	13
	wb	76.0	45.3	14	93.7	32.9	27	89.6	34.9	21	69.7	31.2	25
Thunderbird/40th St	eb	.	.	.	.	.	.	.	.	.	.	.	.
	nb	26.8	17.8	11	39.1	35.3	8	52.3	30.5	17	63.3	42.4	16
	sb	47.6	37.2	45	65.9	120.4	27	42.2	51.0	28	53.8	57.2	23
	wb	13.0	14.0	43	23.0	20.9	32	9.4	10.4	39	10.9	14.0	44
Union Hills/7th St	eb	32.0	19.5	3	49.1	29.6	9	27.6	15.0	18	20.9	13.8	13
	nb	.	.	.	.	.	.	.	.	.	.	.	.
	sb	28.9	18.6	53	25.3	16.3	26	.	.	.	21.8	19.2	44
	wb	24.6	19.6	27	11.8	5.8	16	18.7	10.9	23	18.6	16.4	8
University/Priest	eb	.	.	.	.	.	.	.	.	.	.	.	.
	nb	55.5	22.8	14	35.9	33.0	10	79.4	16.1	11	72.7	12.9	3
	sb	51.1	38.5	18	38.6	29.1	13	60.1	34.9	15	52.5	48.6	11
	wb	58.7	35.4	6	74.0	33.1	10	61.9	22.3	14	75.3	36.8	9
Warner/Arizona Ave	eb	21.5	15.4	13	58.4	38.0	8	34.0	10.9	5	128.5	21.9	2
	nb	45.3	45.1	3	52.3	14.8	7	28.5	6.9	4	56.8	21.5	6
	sb	20.7	9.3	3	17.6	10.7	8	35.0	24.9	5	17.5	21.0	4
	wb	30.2	21.1	9	32.6	13.4	8	28.2	17.1	9	32.4	24.4	9

NotesMean = Mean Travel Time Delay (seconds/vehicle)
Std Dev =Standard Deviation
n = sample Size
.= No Data Available

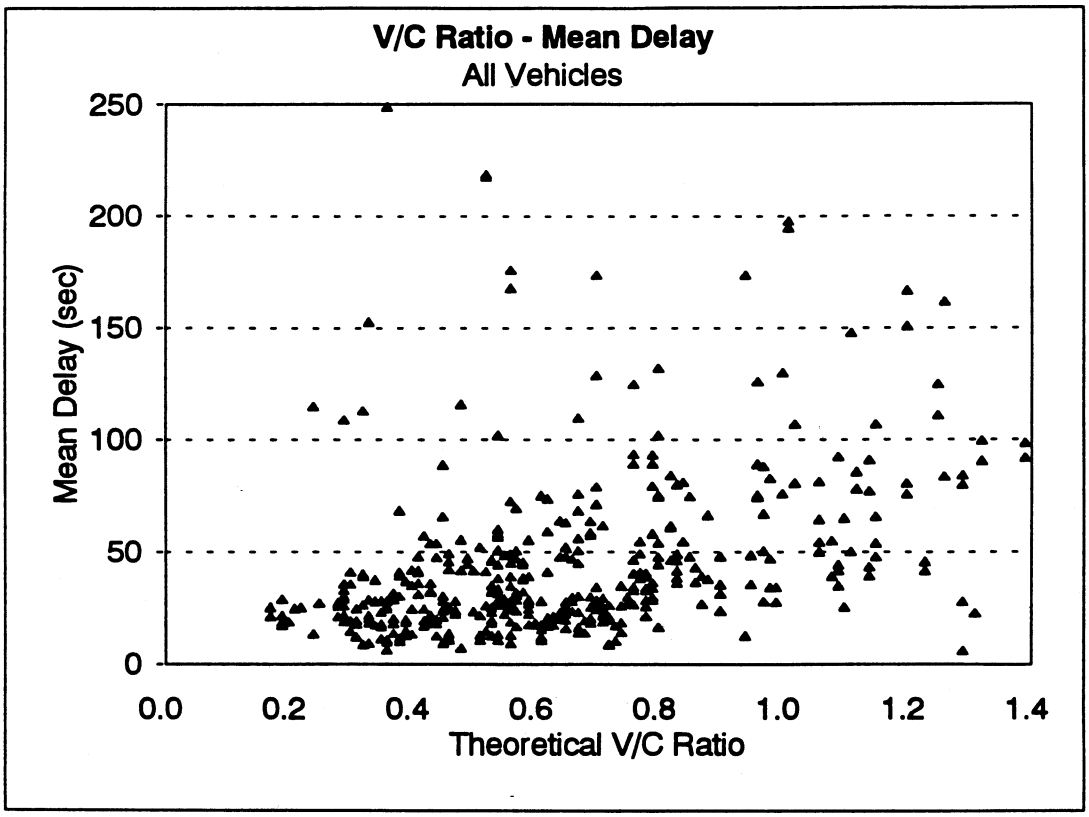


Figure 21. Theoretical V/C Ratio vs. Mean Dealy - All Vehicles

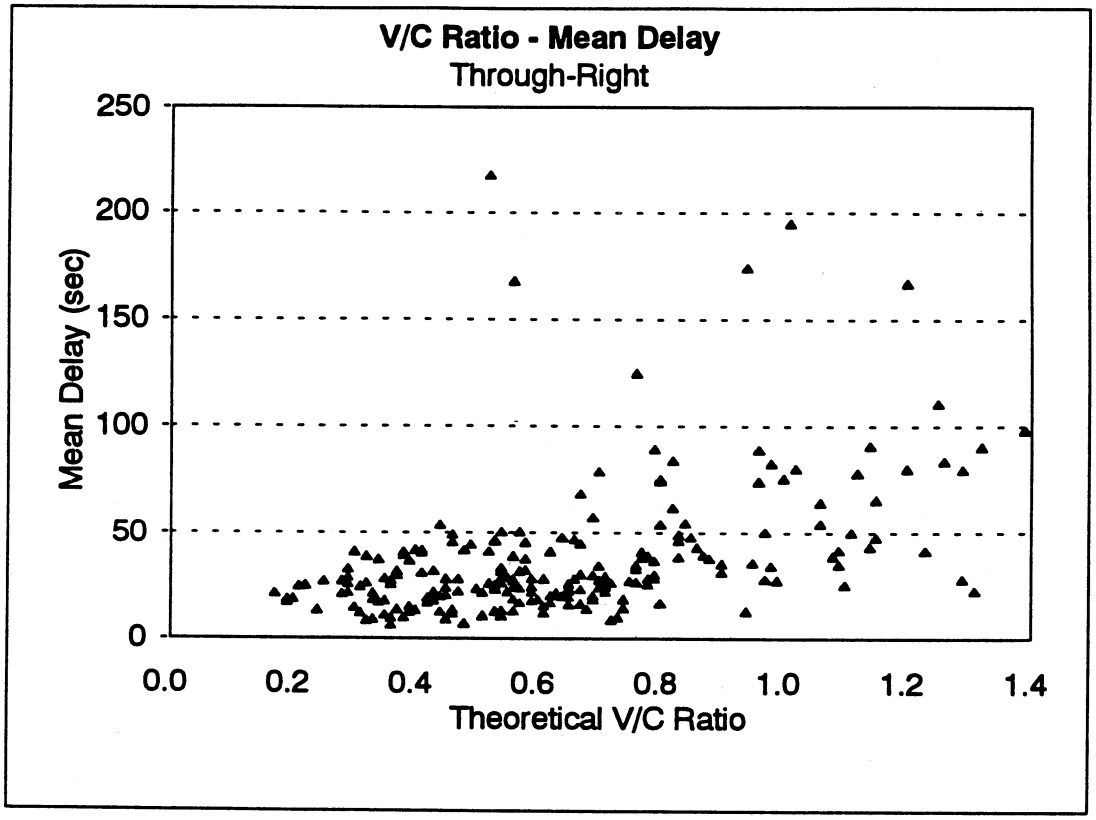


Figure 22. Theoretical V/C Ratio vs. Mean Delay - Through/Right Vehicles

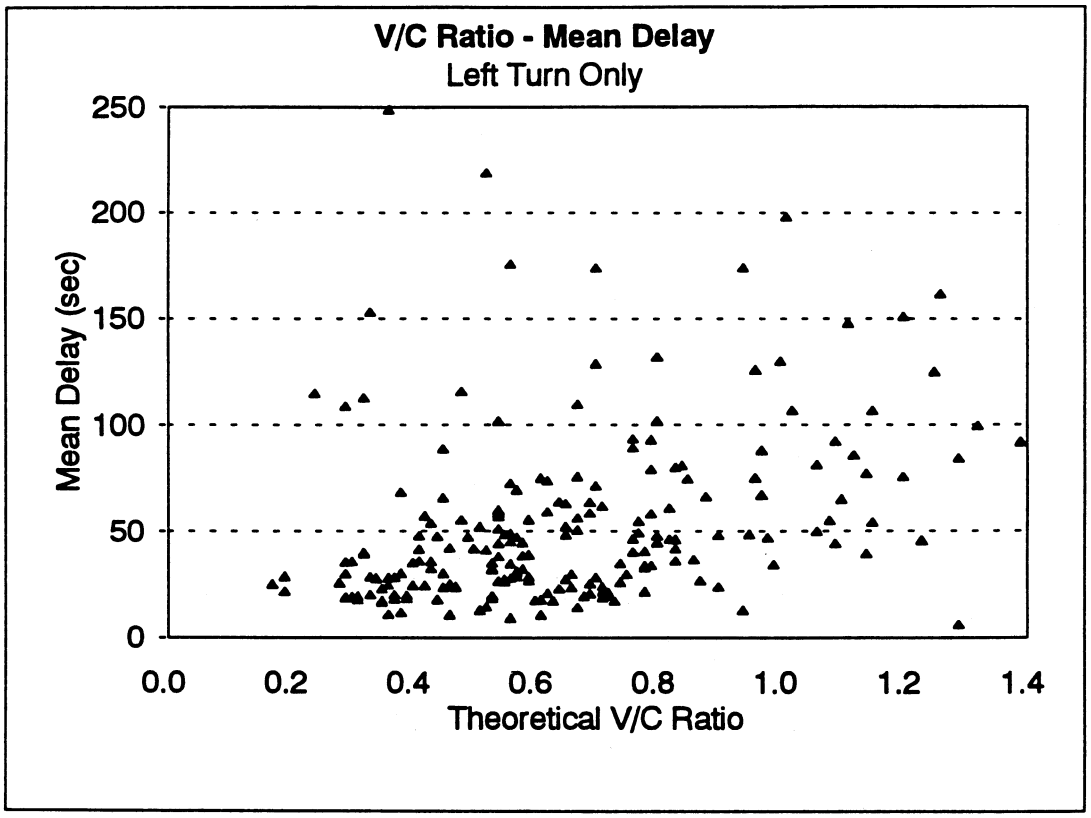


Figure 23.Theoretical V/C Ratio vs. Mean Delay - Left Turning Vehicles

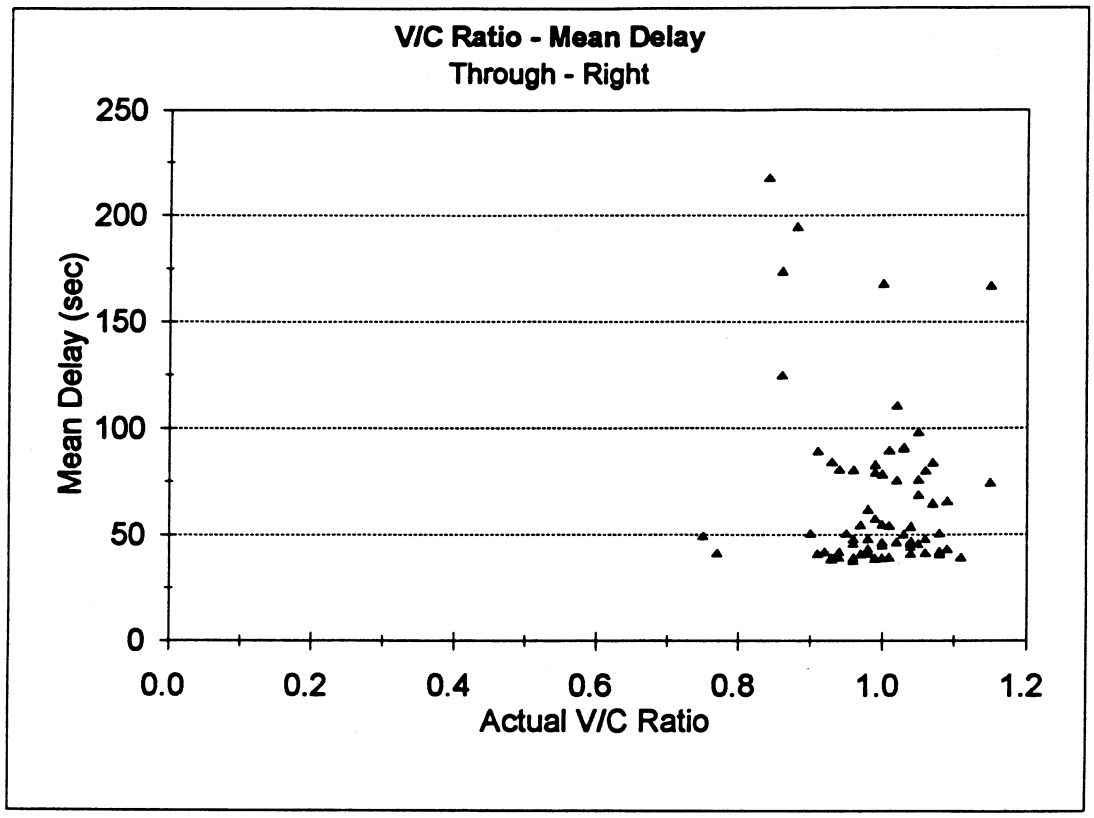


Figure 24. Actual V/C Ratio vs. Mean Dealy - Through/Right Vechicles

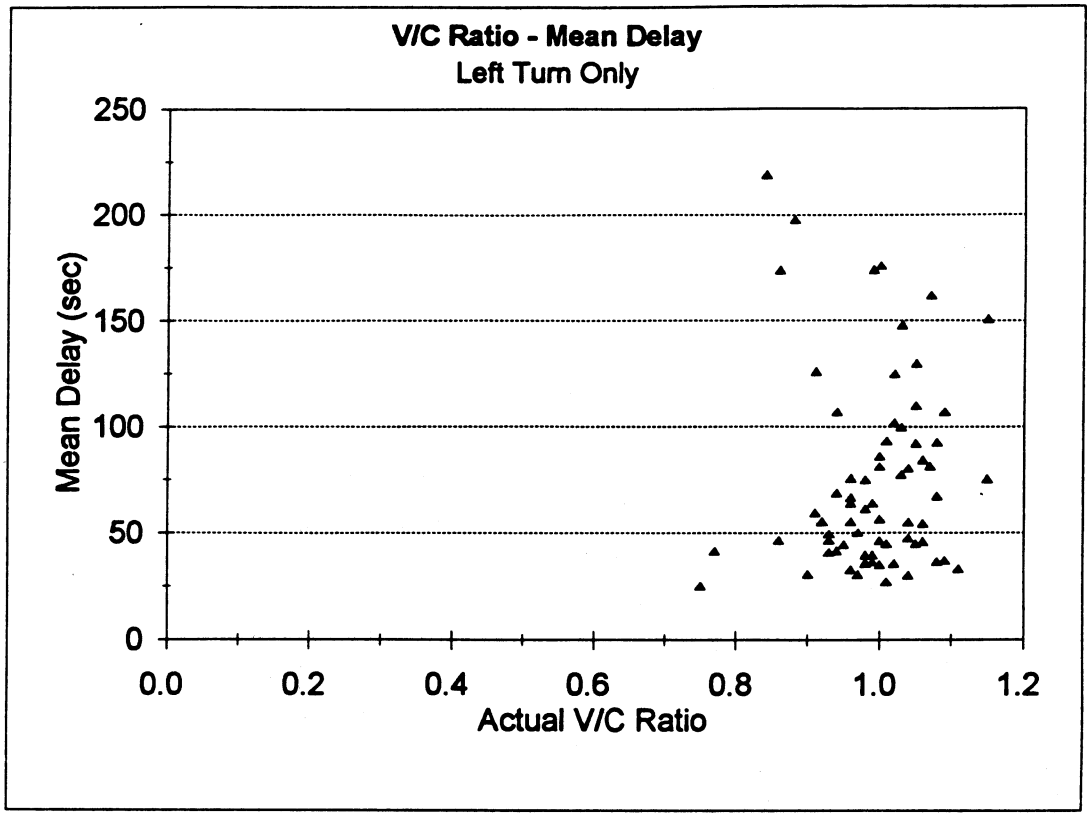


Figure 25. Actual V/C Ratio vs. Mean Delay - Left Turning Vehicles

V. HISTORICAL SPEED CHANGES

This chapter of the report examines speed changes based on travel speed data collected as part of this study, and historic data collected during the previous travel speed studies conducted in 1966, 1970, 1979 and 1986.

The 1986 report also provided an overview of historical speed changes which have occurred in the Phoenix metropolitan area. All historical comparisons conducted for that report were based on the data collection roadway network used for the 1979 study. For this study, two types of comparisons were made. The first comparison includes those a comparison of roadway segments which were part of the 1979 roadway network, and the second is a comparison of common roadway segments between the 1986 and 1993 studies.

It should be noted that the 1979 roadway network consisted of 559 miles of roadways. The 1993 study included only approximately 411 miles of the 559 miles included in the 1979 study. Routes included in the 1979 study which were not included in the 1993 study include Dobbins Road, buckeye Road, McDowell Road, Bethany Home Road, Lincoln Drive, Thunderbird Road, Litchfield Road, 32nd Street, and McClintock Road/Hayden Road.

A second comparison is made between data collected for the midday and evening periods between the 1986 and 1993 studies. Travel speed data was not collected for the morning period during the 1986 study. Approximately 169 miles of roadway surveyed during the midday period in 1993, and 445 miles of roadway surveyed during the evening period in 1993, correlate with roadway segments used in the 1986 study.

Travel Speeds Between Cities

Intercity travel speeds for five major cities are shown in Table 24 for the evening period. The historic speeds were obtained from the 1986 Phoenix Urbanized Area Travel Speed Study and the 1993 travel speeds were derived from the intercity travel times presented previously. The routes between these cities for the 1993 study are included in the appendix.

The results show that overall, there has been an increase in the travel speeds from the various jurisdictions in the evening period. Only the route between Glendale and Scottsdale shows a decrease in travel speed in 1993 over 1986.

Travel Speed Changes

The average travel speed for each jurisdiction for the years between 1966 and 1993 are shown in Table 25. It should be noted that the speeds shown for the years between 1966 and 1986 are based on 1979 the roadway network for the peak direction. The speeds shown for the 1993 analysis year are for the entire study area and include both peak and offpeak directions.

Table 24
Average Late Afternoon Period/Peak Direction Speed
Between Central Business District, 1966 to 1993*

	SPEEDS IN MILES PER HOUR						CHANGE IN SPEEDS	
	1966	1970	1976	1979	1986	1993	1966-1993	1986-1993
Glendale-Scottsdale	33.4	31.6	29.6	26.5	26.8	25.1	-8.3	-1.7
Phoenix-Glendale	24.0	26.2	23.0	23.4	22.6	24.6	-6	2.0
Phoenix-Scottsdale	25.3	27.1	22.1	26.5	22.8	28.4	3.1	5.6
Phoenix-Tempe	25.8	28.4	25.1	28.3	24.4	32.7	6.9	8.3
Tempe-Scottsdale	28.5	24.2	25.0	23.9	17.0	20.6	-7.9	3.6
Tempe-Mesa	32.0	30.7	25.7	25.0	19.6	29.3	-2.7	9.7

Speeds for 1966, 1970, 1976, 1979 and 1986 are from the 1986 Phoenix Urbanized Area Travel Speed Study.
* See Appendix for details on location of central business districts and path of travel between cities.

These data show that for the most part average travel speed has increased since 1986. The most significant decrease is in freeway segments in Tempe where average speed has dropped rather significantly.

Changes in Travel Speed between 1986 and 1993

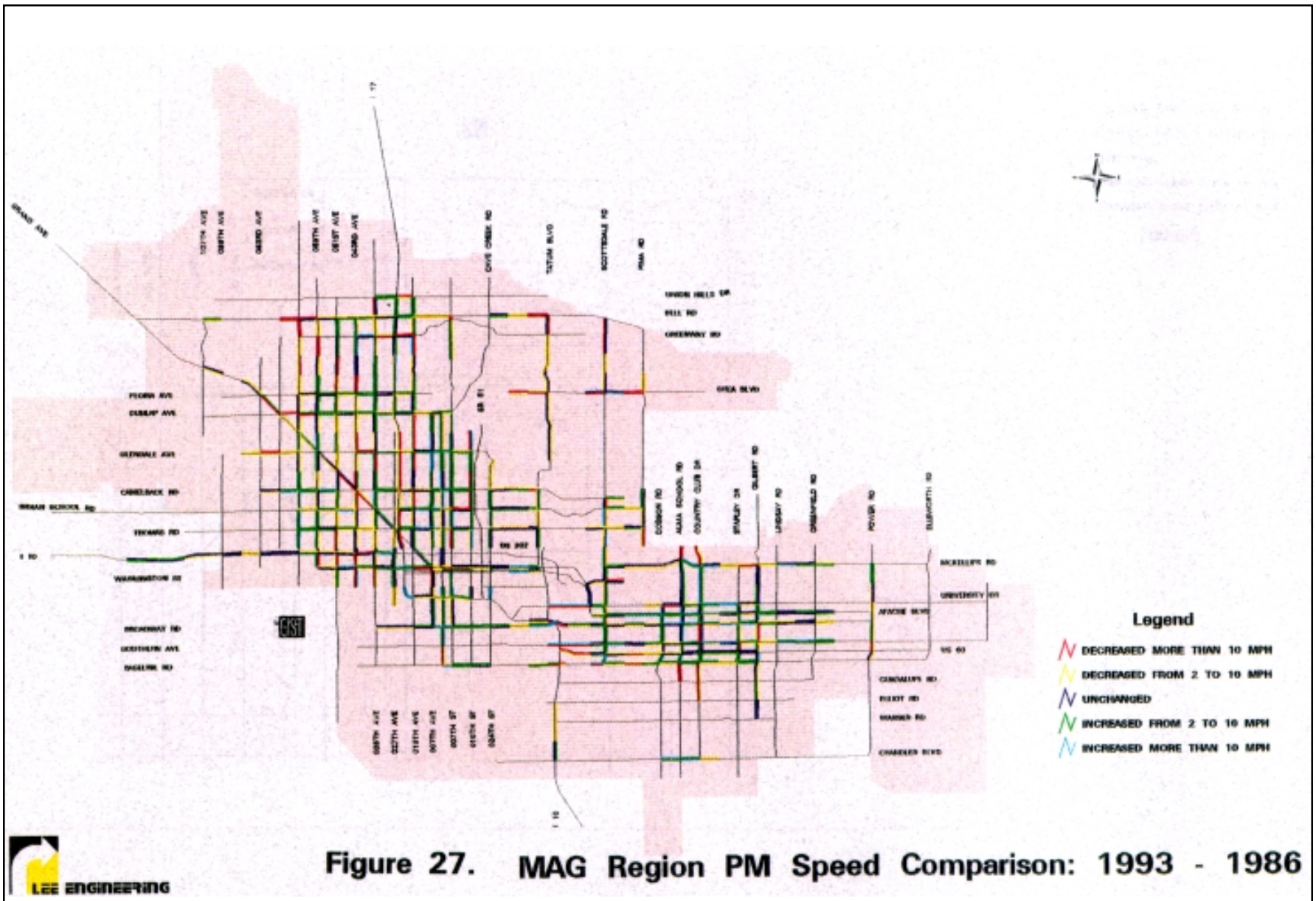
A comparison was made of the speed changes on individual roadway segments between the 1993 and 1986 travel speed studies. To do this the data files were obtained from the 1986 study. The roadway segments included in the 1986 study were mapped into the 1993 study segments and the overlapping segments defined. The average travel speeds for the matching 1986 and 1993 roadway segments were then compared.

The results of the comparison for the midday and evening periods are shown in Figures 26 and 27.

There is no definable pattern of increase or decrease of travel speed. It should be noted that each segment is a point sample with 3 or 4 samples both in the 1986 and 1993 study.

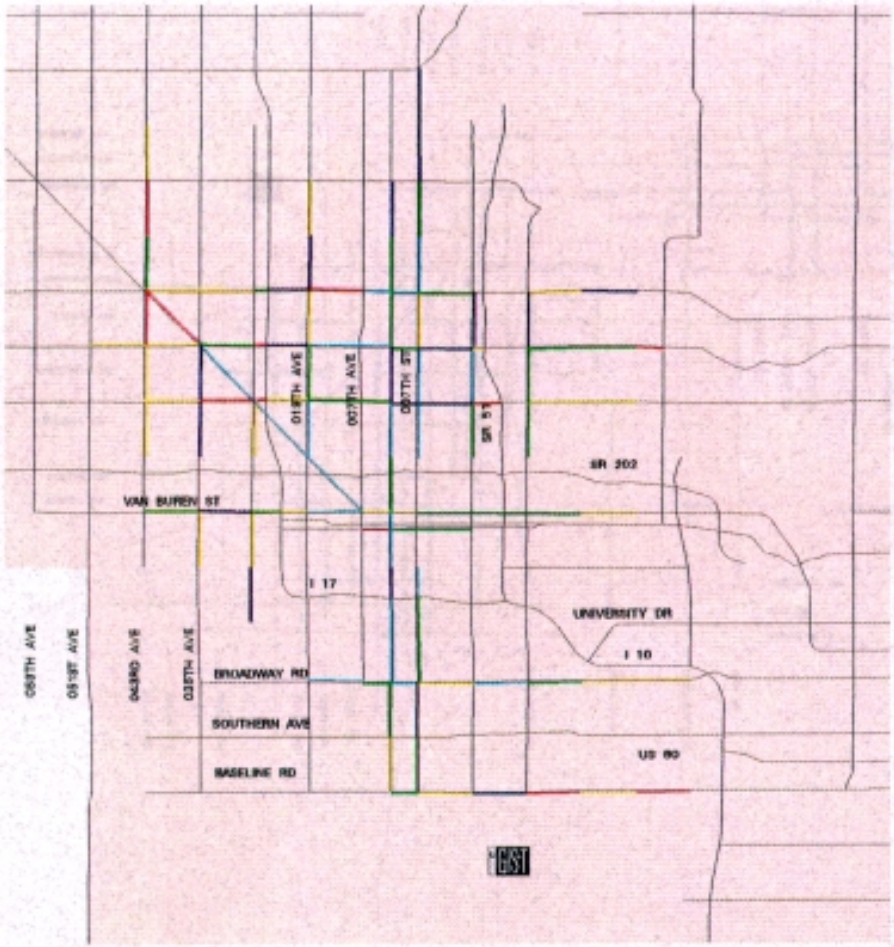
City of Phoenix Speed Changes

A comparison was also made of the speed changes between the 1993 and 1957 travel speed studies. The 1957 speed study was the earliest of the speed studies and included 151 roadway miles. The comparison included an estimate of VMT on the roadway segments which comprised the original study area as well as a plot of the changes in speed on a segment by segment basis between 1957 and 1993



LEE ENGINEERING

Figure 27. MAG Region PM Speed Comparison: 1993 - 1986



Legend

- DECREASED MORE THAN 10 MPH
- DECREASED FROM 2 TO 10 MPH
- UNCHANGED
- INCREASED FROM 2 TO 10 MPH
- INCREASED MORE THAN 10 MPH

LEE ENGINEERING

Figure 28. City of Phoenix PM Speed Comparison: 1993 - 1957 (Peak Direction)

APPENDIX

DESCRIPTION OF VARIABLES IN THE DATA SUMMARY TABLE

Abbrey.	Data Name	Description
Location		A five character alpha-numeric code that uniquely identifies the intersection. The first three letters/digits represent the first three letters/digits of the east-west street. The last two letters represent the first two letters/digits of the north-south street. For example: warar-WARneer Rd @ ARizona Ave
Dir	Direction	The particular approach that the following data applies to.
Int	Interval	The particular interval that the following data applies to. The interval are defined by the following times: Interval 1: 4:30-4:45 p.m Interval 2: 4:45-5:00 p.m Interval 3: 5:00-5:15 p.m. Interval 4: 5:15-5:30 p.m.
Up Vol	Upstream Volume	The 15-minute volume measured at the upstream position.
Down Vol	Downstream Volume	The 15-minute volume measured at the intersection.
SFR	Saturation Flow Rate	The overall saturation flow rate for the intersection.
Sat	Saturated	"Y" if approach is saturated within that interval, "N" if not.
Mean Delay		The average stopped time delay (in seconds) for a particular approach interval.
Theor Cap	Theoretical Capacity	A calculated value determined from the SFR, g/C, and lanes.
Theor V/C	Theoretical V/C Ratio	Calculated by dividing UP VOL by THEOR CAP.
Act V/C	Actual V/C	Calculated by dividing UP VOL by DOWN VOL for saturated approaches only.
g/C	g/C Ratio	Through movement g/C ratio. Calculated by summing the through green times for an entire interval and dividing by the number of seconds in an interval.

LT g/C	L.Turn g/C	Left turn g/C ratio. Calculated by summing green times for left turn arrows and dividing by the number of seconds in an interval.
Green	Thru Green Time	The sum of through movement green times (seconds)
LT Green	Left Turn Green Time	The sum of the left turn movement green times (seconds)
Facil Type	Facility Type	The type of facility as defined by MAG: Code — Type 1 — Principal Arterial 2 — Minor Arterial 3 — Urban Collector
Area Type		The type of area as defined by MAG: Code — Type 1 — Urban Core 2 — Urban 3 — Suburban
LT Lane	Left Turn Lanes	The number of exclusive left turn lanes
Thru Lane		The number of exclusive and shared thru lanes.
RT Lane	Right Turn Lanes	The number of exclusive right turn lanes.
Actuated		"1" if signal is actuated, "0" if not.
Phasing	Left Turn Phasing	The type of left turn phasing used on the approach. Code — Type 1 — Permissive 2 — Permissive/Protected 3 — Protected
Left Clear Time	Left Turn Clearance	The Yellow + All Red clearance interval (in seconds) for the left turn phase (if any).

Thru Clear Time	Through Clearance Time	The Yellow + All Red clearance interval (in seconds) for the through phase.
Lost Time		The startup lost time (in seconds) at the intersection.

SAMPLE OF FINAL.DEL FILE

Soumc 13 2 1 16:30:13 16:30:00 T nb
soumc 9 0 1 16:30:09 16:30:00 Tnb
soumc 5 0 1 16:30:05 16:30:00 L nb
soumc 23 12 1 16:30:05 16:30:00 T nb
soumc 25 14 1 16:30:25 16:30:00 T nb
soumc 18 7 1 16:30:18 16:30:00 T nb
soumc 23 12 1 16:30:23 16:30:00 T nb
soumc 18 7 1 16:30:18 16:30:00 T nb
soumc 16 5 1 16:30:16 16:30:00 T nb
soumc 20 9 1 16:30:20 16:30:00 T nb
soumc 31 20 1 16:30:31 16:30:00 T nb
soumc 32 21 1 16:30:32 16:30:00 T nb
soumc 24 13 1 16:30:24 16:30:00 T nb
soumc 27 16 1 16:30:27 16:30:00 T nb
soumc 23 12 1 16:30:23 16:30:00 T nb
gle00 21 5 1 16:34:07 16:33:46 T nb
gle00 22 6 1 16:34:09 16:33:47 T nb
gle00 24 8 1 16:34:12 16:33:48 T nb
gle00 18 2 1 16:34:09 16:33:51 Tnb
gle00 19 3 1 16:34:11 16:33:52 T nb
gle00 20 4 1 16:34:12 16:33:52 T nb
gle00 18 2 1 16:34:12 16:33:54 T nb
gle00 18 2 1 16:34:13 16:33:55 T nb
gle00 19 3 1 16:34:15 16:33:56 T nb
gle00 20 4 1 16:34:17 16:33:57 T nb
gle00 18 2 1 16:34:17 16:33:59 T nb
gle00 14 0 1 16:34:15 16:34:01 T nb
gle00 19 3 1 16:34:27 16:34:08 T nb
warar 15 1 1 16:33:16 16:33:01 T nb
warar 14 0 1 16:33:20 16:33:06 T nb
warar 73 59 1 16:32:57 16:31:44 T nb
warar 38 24 1 16:32:59 16:32:21 T nb
warar 29 15 1 16:33:03 16:32:34 T nb
warar 29 15 1 16:33:04 16:32:35 T nb
warar 24 10 1 16:33:06 16:32:42 T nb
warar 17 3 1 16:33:09 16:32:52 T nb
warar 16 2 1 16:33:14 16:32:58 T nb
warar 16 2 1 16:33:14 16:32:58 T nb
warar 15 1 1 16:33:16 16:33:01 T nb
warar 56 42 1 16:34:06 16:33:10 T nb
warar108 94 1 16:32:48 16:31:00 L nb
warar 53 39 1 16:33:31 16:32:38 T nb

SAMPLE OF FINAL.SIG FILE

Loc	Int	Dir	LGrn	TGrn	Lg-c	Tg-c	facil	area	Thru	Left	Right	Act	Phase	Clear	Lost
gle00	1	nb	0	419	0.00	0.47	1	2	2	1	0	0	1	4	3
gle00	1	sb	0	419	0.00	0.47	2	2	2	1	0	0	1	4	3
gle00	1	eb	0	421	0.00	0.47	1	2	3	1	0	0	1	4	3
gle00	1	wb	0	421	0.00	0.47	1	2	2	1	0	0	1	4	3
gle00	2	nb	0	455	0.00	0.51	1	2	2	1	0	0	1	4	3
gle00	2	sb	0	455	0.00	0.51	2	2	2	1	0	0	1	4	3
gle00	2	eb	0	385	0.00	0.43	1	2	3	1	0	0	1	4	3
gle00	2	wb	0	385	0.00	0.43	1	2	2	1	0	0	1	4	3
gle00	3	nb	0	470	0.00	0.52	1	2	2	1	0	0	1	4	3
gle00	3	sb	0	470	0.00	0.52	2	2	2	1	0	0	1	4	3
gle00	3	eb	0	370	0.00	0.41	1	2	3	1	0	0	1	4	3
gle00	3	wb	0	370	0.00	0.41	1	2	2	1	0	0	1	4	3
gle00	4	nb	0	470	0.00	0.52	1	2	2	1	0	0	1	4	3
gle00	4	sb	0	470	0.00	0.52	2	2	2	1	0	0	1	4	3
gle00	4	eb	0	370	0.00	0.41	1	2	3	1	0	0	1	4	3
gle00	4	wb	0	370	0.00	0.41	1	2	2	1	0	0	1	4	3
soumc	1	nb	72	320	0.08	0.36	1	1	3	2	1	0	3	6	3
soumc	1	sb	83	331	0.09	0.37	1	1	3	2	1	0	3	6	3
soumc	1	eb	62	249	0.07	0.28	2	1	3	2	0	0	3	6	3
soumc	1	wb	74	261	0.08	0.29	2	1	3	2	0	0	3	6	3
soumc	2	nb	79	333	0.09	0.37	1	1	3	2	1	0	3	6	3
soumc	2	sb	84	335	0.09	0.37	1	1	3	2	1	0	3	6	3
soumc	2	eb	66	234	0.07	0.26	2	1	3	2	0	0	3	6	3
soumc	2	wb	86	254	0.10	0.28	2	1	3	2	0	0	3	6	3
soumc	3	nb	86	309	0.10	0.34	1	1	3	2	1	0	3	6	3
soumc	3	sb	87	319	0.10	0.35	1	1	3	2	1	0	3	6	3
soumc	3	eb	82	240	0.09	0.27	2	1	3	2	0	0	3	6	3
soumc	3	wb	93	249	0.10	0.28	2	1	3	2	0	0	3	6	3
soumc	4	nb	74	310	0.08	0.34	1	1	3	2	1	0	3	6	3
soumc	4	sb	89	320	0.10	0.36	1	1	3	2	1	0	3	6	3
soumc	4	eb	67	260	0.07	0.29	2	1	3	2	0	0	3	6	3
soumc	4	wb	71	294	0.08	0.33	2	1	3	2	0	0	3	6	3
warar	1	nb	54	316	0.06	0.35	1	2	3	1	0	0	2	6	3
warar	1	sb	64	337	0.07	0.37	1	2	3	1	0	0	2	6	3
warar	1	eb	58	266	0.06	0.30	1	2	2	1	1	0	2	6	3
warar	1	wb	63	276	0.07	0.31	2	2	2	1	1	0	2	6	3
warar	2	nb	79	371	0.09	0.41	1	2	3	1	0	0	2	6	3
warar	2	sb	62	349	0.07	0.39	1	2	3	1	0	0	2	6	3
warar	2	eb	68	227	0.08	0.25	1	2	2	1	1	0	2	6	3
warar	2	wb	65	219	0.07	0.24	2	2	2	1	1	0	2	6	3
warar	3	nb	75	324	0.08	0.36	1	2	3	1	0	0	2	6	3
warar	3	sb	63	307	0.07	0.34	1	2	3	1	0	0	2	6	3
warar	3	eb	60	284	0.07	0.32	1	2	2	1	1	0	2	6	3
warar	3	wb	58	272	0.06	0.30	2	2	2	1	1	0	2	6	3
warar	4	nb	79	402	0.09	0.45	1	2	3	1	0	0	2	6	3
warar	4	sb	64	354	0.07	0.39	1	2	3	1	0	0	2	6	3
warar	4	eb	55	226	0.06	0.25	1	2	2	1	1	0	2	6	3
warar	4	wb	62	233	0.07	0.26	2	2	2	1	1	0	2	6	3

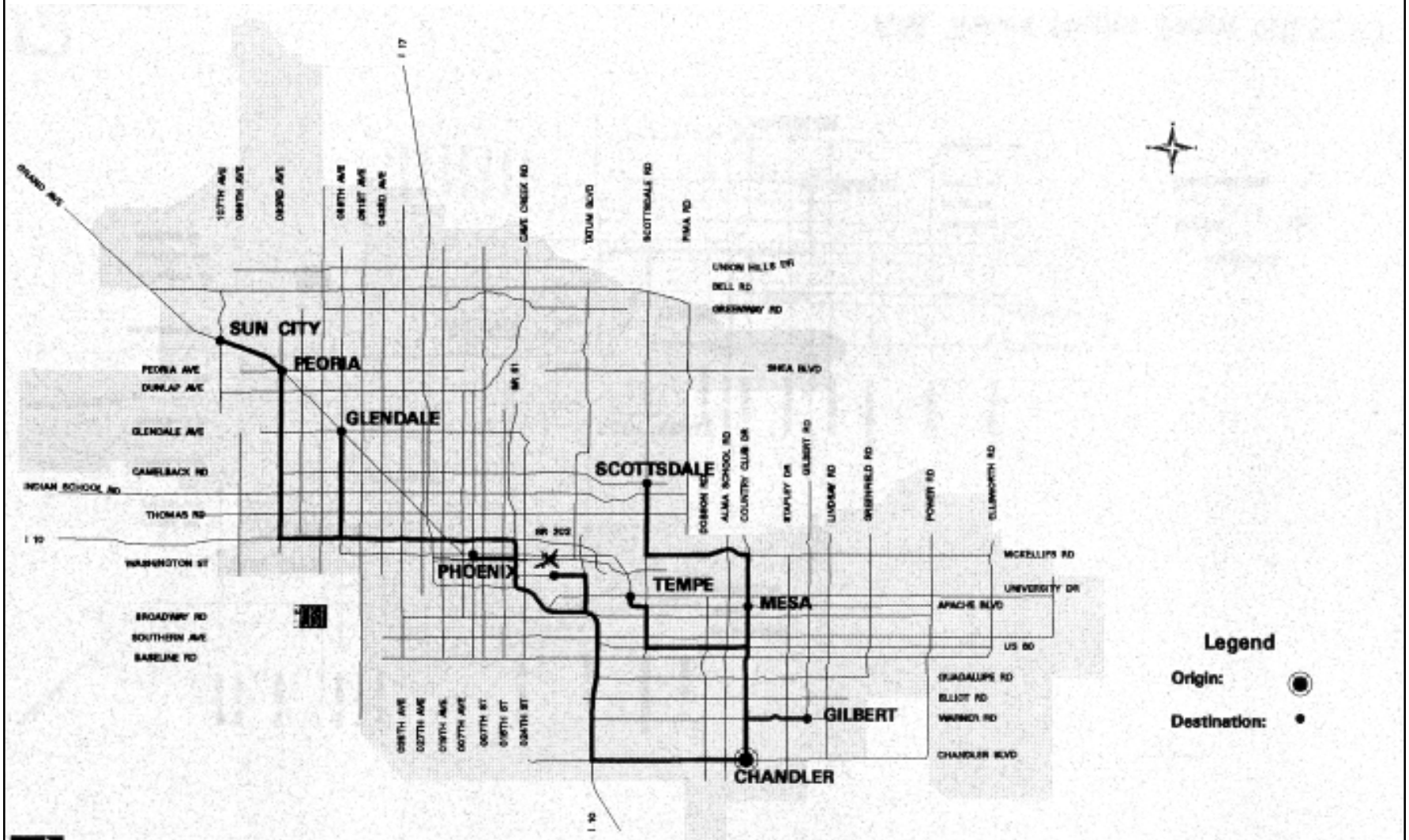
SAMPLE OF FINAL.VOL FILE

name	int	dir	down	up	delay	sfr	sat
gle00	1	eb	321	323	9.99	1940	N
gle00	2	eb	303	311	8.35	1940	N
gle00	3	eb	332	333	13.62	1940	N
gle00	4	eb	379	393	17.35	1940	N
gle00	1	nb	345	348	19.48	1940	N
gle00	2	nb	428	419	61.79	1940	Y
gle00	3	nb	487	466	45.98	1940	Y
gle00	4	nb	419	427	77.35	1940	Y
gle00	1	sb	166	162	20.28	1940	N
gle00	2	sb	140	135	26.77	1940	N
gle00	3	sb	186	187	25.19	1940	N
gle00	4	sb	206	204	11.36	1940	N
gle00	1	wb	359	380	17.3	1940	Y
gle00	2	wb	375	377	39.07	1940	N
gle00	3	wb	345	306	24.4	1940	N
gle00	4	wb	378	350	83.57	1940	Y
soumc	1	eb	395	411	48.67	1900	Y
soumc	2	eb	387	444	74.51	1900	Y
soumc	3	eb	487	503	90.23	1900	Y
soumc	4	eb	472	466	82.92	1900	Y
soumc	1	nb	402	388	37.06	1900	N
soumc	2	nb	385	405	45.49	1900	N
soumc	3	nb	404	388	33.4	1900	N
soumc	4	nb	450	455	35.77	1900	Y
soumc	1	sb	563	607	30.34	1900	Y
soumc	2	sb	554	586	36.23	1900	Y
soumc	3	sb	586	630	43.04	1900	Y
soumc	4	sb	586	627	67.58	1900	Y
soumc	1	wb	272	287	30.69	1900	N
soumc	2	wb	307	320	47.41	1900	N
soumc	3	wb	317	319	40.01	1900	N
soumc	4	wb	305	289	35.07	1900	N
warar	1	eb	311	319	25.66	1938	Y
warar	2	eb	267	297	30.76	1938	Y
warar	3	eb	325	342	26.33	1938	Y
warar	4	eb	275	260	26.32	1938	Y
warar	1	nb	304	300	19.66	1938	N
warar	2	nb	328	321	23.9	1938	N
warar	3	nb	397	373	27.69	1938	N
warar	4	nb	352	368	30.24	1938	N
warar	1	sb	365	398	18.57	1938	N
warar	2	sb	478	388	18.61	1938	N
warar	3	sb	363	411	15.5	1938	N
warar	4	sb	506	403	21.4	1938	N
warar	1	wb	182	152	26.37	1938	N
warar	2	wb	171	157	32.16	1938	N
warar	3	wb	196	160	27.61	1938	N
warar	4	wb	209	197	32.42	1938	N

DELAYSUM.SAS FILE

```
DATA DELDAT;
INPUT NOWREAD $40.;
INFILE MYINPUT SHAREBUFFERS END=DONE FILEVAR=NOWREAD FIRSTOBS=1;
DO WHILE (DONE NE 1);
        INPUT LOC & TTLDEL STPDEL INTV TIME2 time9. time1 time9.          TURN  $ DIR  $;
        output;
END;
CARDS;
D:\SASDATA\TRAVSPD\PRELIM.DEL
;

DATA VOLDAT;
INPUT NOWREAD $40.;
INFILE MYINPUT SHAREBUFFERS END=DONE FILEVAR=NOWREAD FIRSTOBS=3;
DO WHILE (DONE NE 1);
        INPUT LOC $ INTV DIR $ DOWN UP GARB SFR SAT $;
        output;
END;
CARDS;
D:\SASDATA\TRAVSPD\PRELIM.VOL
;

DATA SIGDAT;
INPUT NOWREAD $40.;
INFILE MYINPUT SHAREBUFFERS END=DONE FILEVAR=NOWREAD FIRSTOBS=7;
DO WHILE (DONE NE 1);
        INPUT LOC $ INTV DIR $ LGREEN GREEN LG_C G_C FACILITY AREA T_LANES
        L_LANES R_LANES ACT PHASE CLEAR LOST;
        output;
END;
CARDS;
D:\SASDATA\TRAVSPD\PRELIM.SIG
;

RUN;

PROC SORT DATA = VOLDAT;
        BY LOC DIR INTV;
PROC SORT DATA = SIGDATA;
        BY LOC DIR INTV;
PROC SORT DATA = DELDAT;
        BY LOC DIR INTV;
RUN;

DATA VOLSIG;
        MERGE VOLDAT SIGDAT;
        BY LOC DIR INTV;

DATA FINAL;
        MERGE VOLSIG DELDAT;
        BY LOC DIR INTV;
        LABEL STPDEL = 'STOP DELAY'
                        LOC = 'Location'
                        DIR = 'Direction'
                        INTV = 'Interval';

RUN;

PROC SORT DATA = FINAL;
        BY LOC DIR INTV TURN;
RUN;

PROC TABULATE DATA = FINAL;
        OPTIONS LINESIZE = 175 PAGESIZE = 45;
        CLASS LOC DIR INTV TURN;
```

```
        VAR STPDEL;
        TABLE TURN, LOC*DIR, INTV*(STPDEL*(MEAN*F=8.1 STD*F=8.1 N*F=6.0)) / RTS =
26;
        KEYLABEL STD = 'Std Dev';
        KEYLABEL MEAN =' Mean';
RUN;

DATA MAGFILE (KEEP=LOC INTV DIR TURN SFR SAT MNDELAY TH_CAP TH_V_C ACT _V_C
                        LGREEN GREEN LG_C G_C FACILITY AREA T_LANES L_LANES
                        R_LANES ACT PHASE CLEAR LOST DOWN UP);
        SET FINAL;
          BY LOC DIR INTV TURN;
        IF FIRST.TURN THEN DO;
                        SUMDELAY = 0;
                        SAMPLE = 0;
        END;
        SUMDELAY + STPDEL;
        SAMPLE + 1;
        IF LAST.TURN THEN DO;
                        MNDELAY = SUMDELAY/SAMPLE;
                        TH_CAP = .25 * SFR * G_C * T_LANES;
                        TH_V_C = UP / TH_CAP;
                        IF SAT = 'Y' THEN DO;
                                ACT_V_C = UP / DOWN;
                                END;
                        OUTPUT MAGFILE;
        END;
RUN;
PROC PRINT NOOBS SPLIT='*' UNIFORM;
        VAR LOC DIR INTV TURN UP DOWN SFR SAT MNDELAY TH_CAP TH_V_C ACT_V_C
                        G_C LG_C GREEN LGREEN FACILITY AREA T_LANES L_LANES R_LANES
                        ACT PHASE CLEAR LOST;
                        LABEL LOC = 'Location'
                          DIR = 'Dir'
                          INTV = 'Int'
                          TURN = 'Turn'
                          UP = 'Up*Vol'
                          DOWN = 'Down*Vol'
                          SFR = 'SFR'
                          SAT = 'Sat'
                          MNDELAY = 'Mean*Delay'
                          TH-CAP = 'Theor*Cap'
                          TH_V_C_ = 'Theor*V/C'
                          ACT_V_C = 'Act*V/C'
                          G_C = 'g/c'
                          LG_C = 'LT*g/C'
                          GREEN = 'Green'
                          LGREEN = 'LT*Green'
                          FACILITY = 'Facil*Type'
                          AREA = 'Area*Type'
                          T_LANES = 'Thru*Lane'
                          L_LANES = 'LT*Lane'
                          R_LANES = 'RT*Lane'
                          ACT = 'Actuated'
                          PHASE = 'Phasing'
                          CLEAR = 'Clear*Time'
                          LOST = 'Lost*Time';
        FORMAT MNDELAY 4.1 CLEAR LOST 3.1 TH_CAP 5. G_C LG_C TH_V_C ACT_V_C 4.2;
        TITLE 'Data Summary Table for Preliminary Intersections';
RUN;
```



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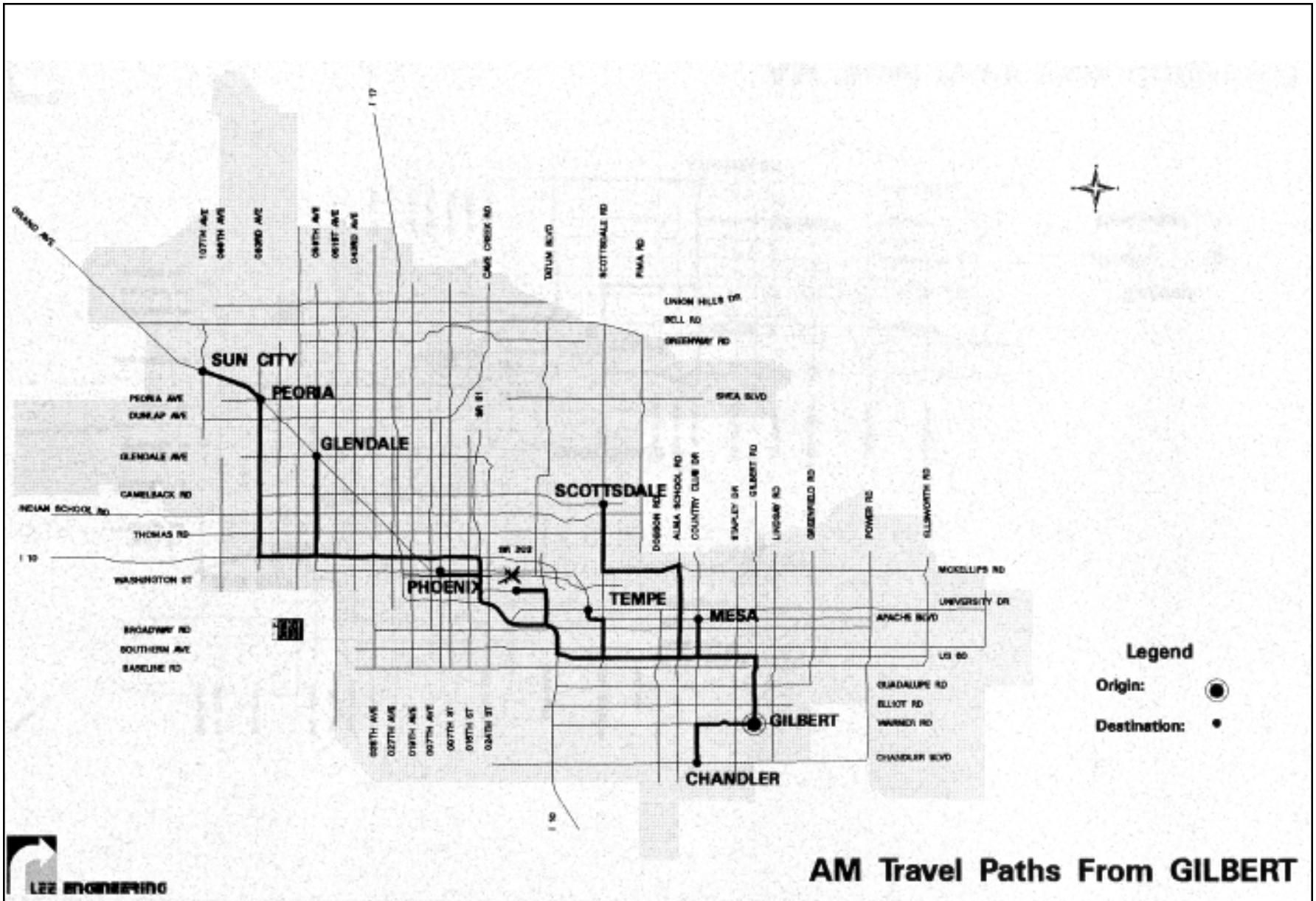
AM Travel Paths From CHANDLER



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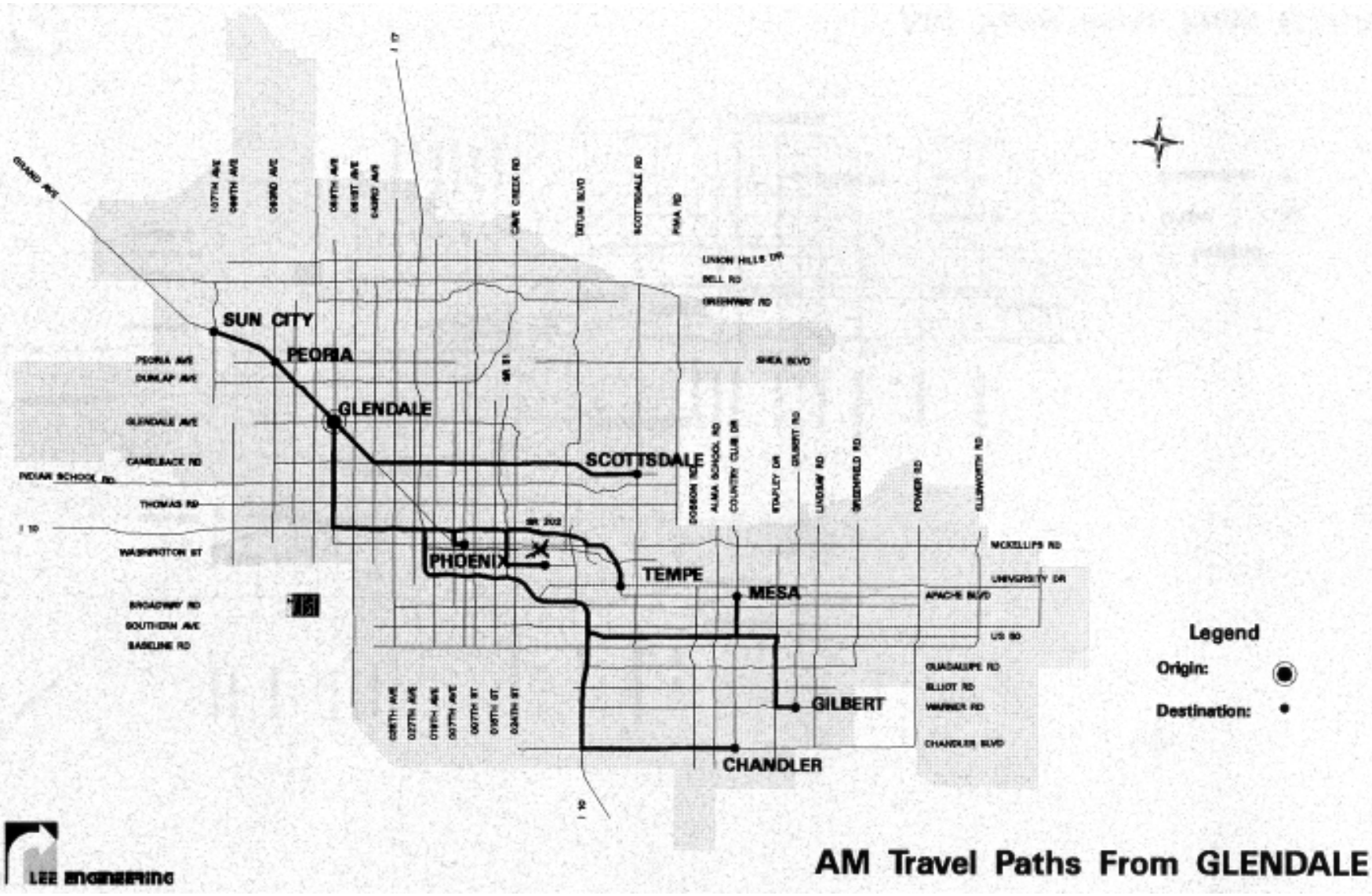
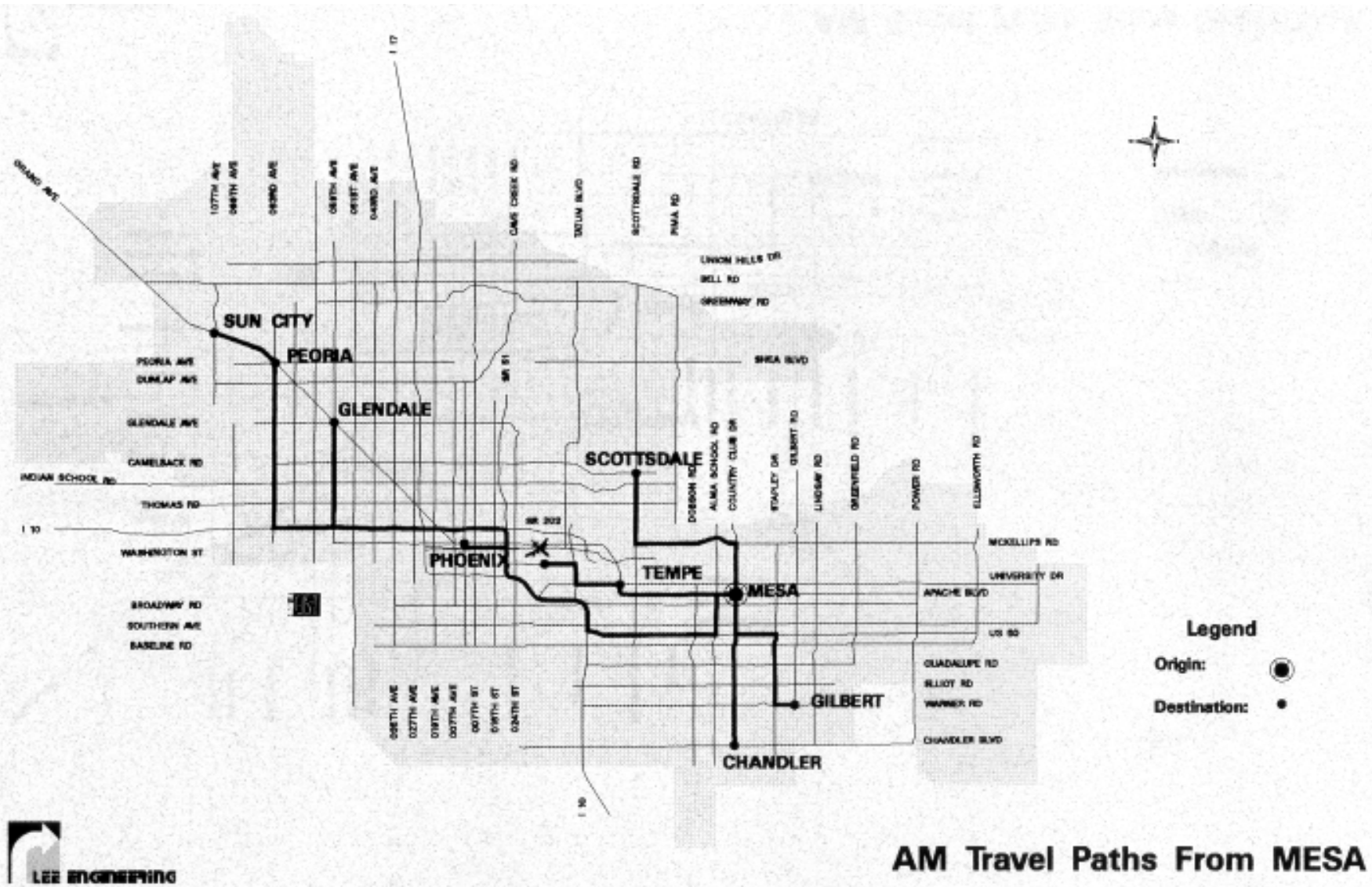
AM Travel Paths From GILBERT


SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TEMPE
MESA
GILBERT
CHANDLER
Legend
Origin:
Destination:
LEE ENGINEERING
AM Travel Paths From GLENDALE



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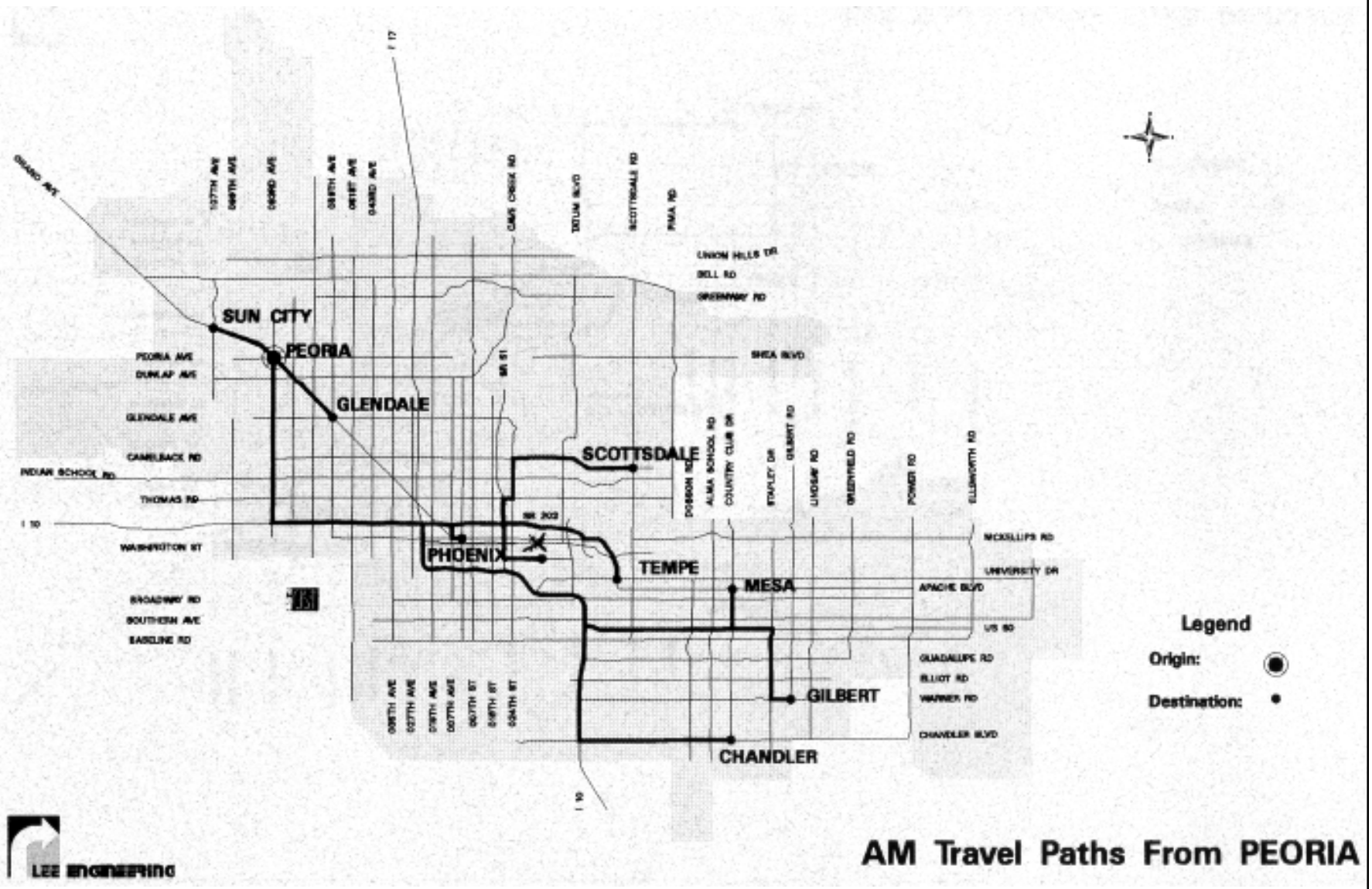
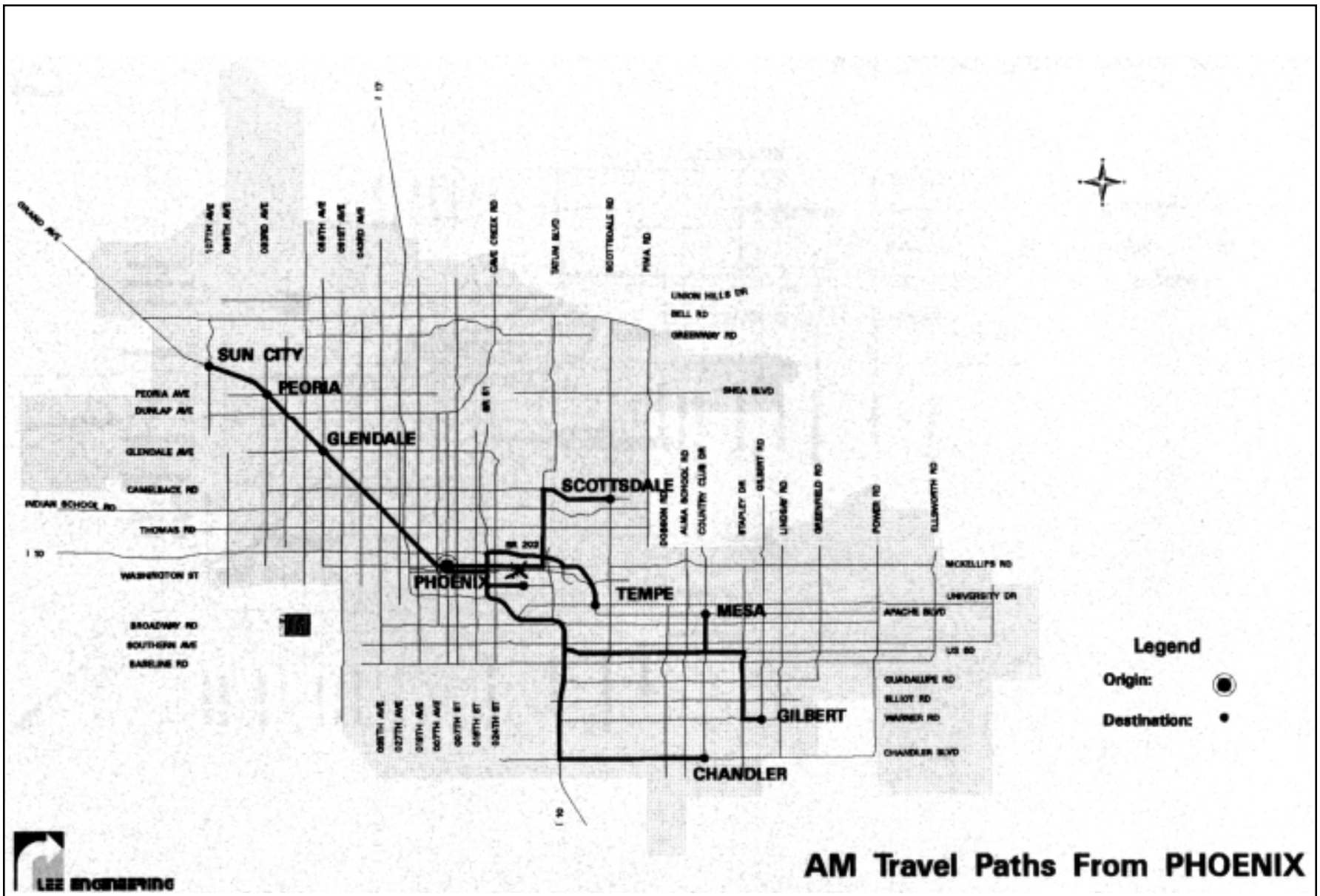
AM Travel Paths From MESA


SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TEMPE
MESA
GILBERT
CHANDLER
Legend
Origin:
Destination:
LEE engineering
AM Travel Paths From PEORIA



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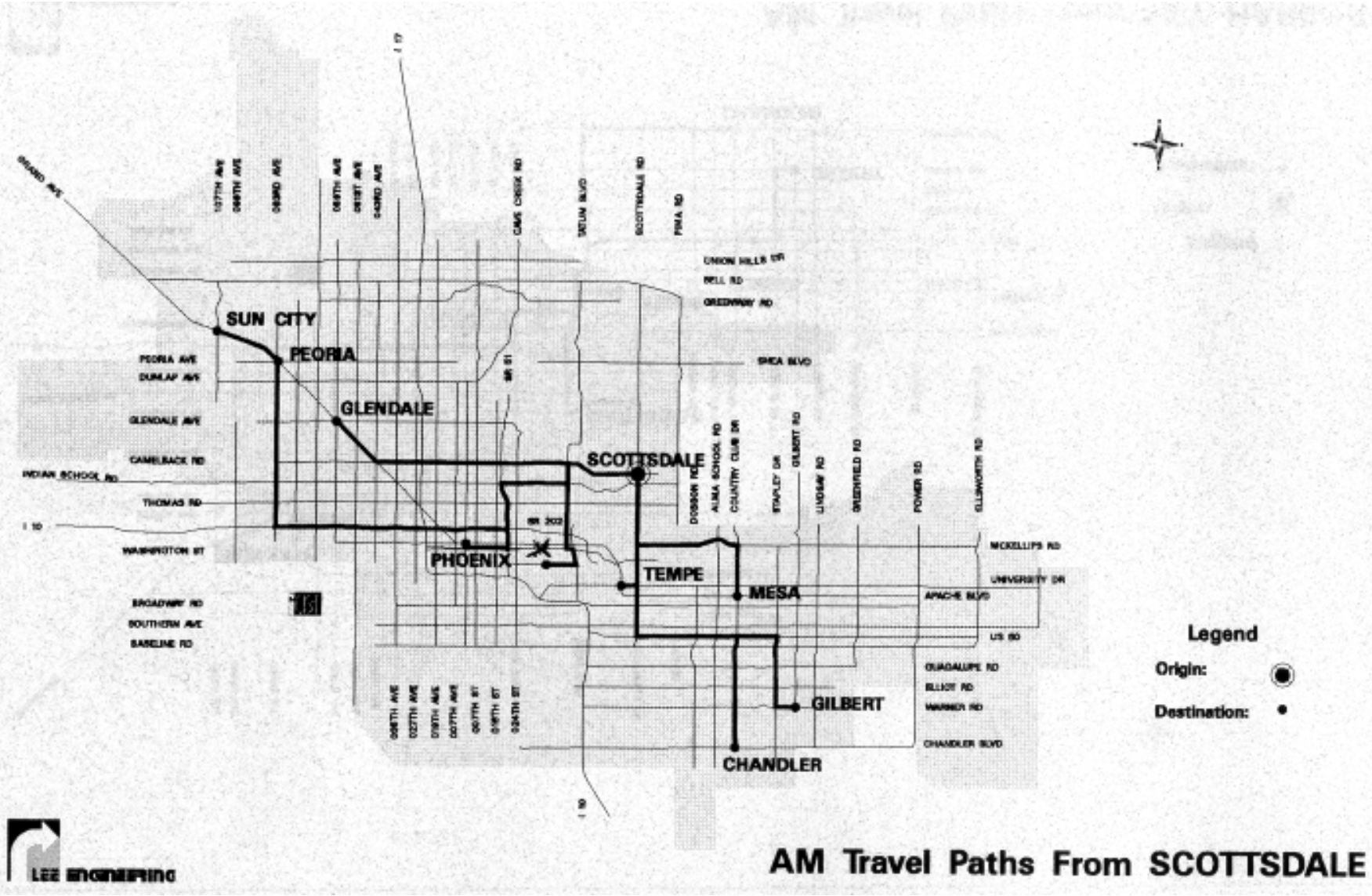
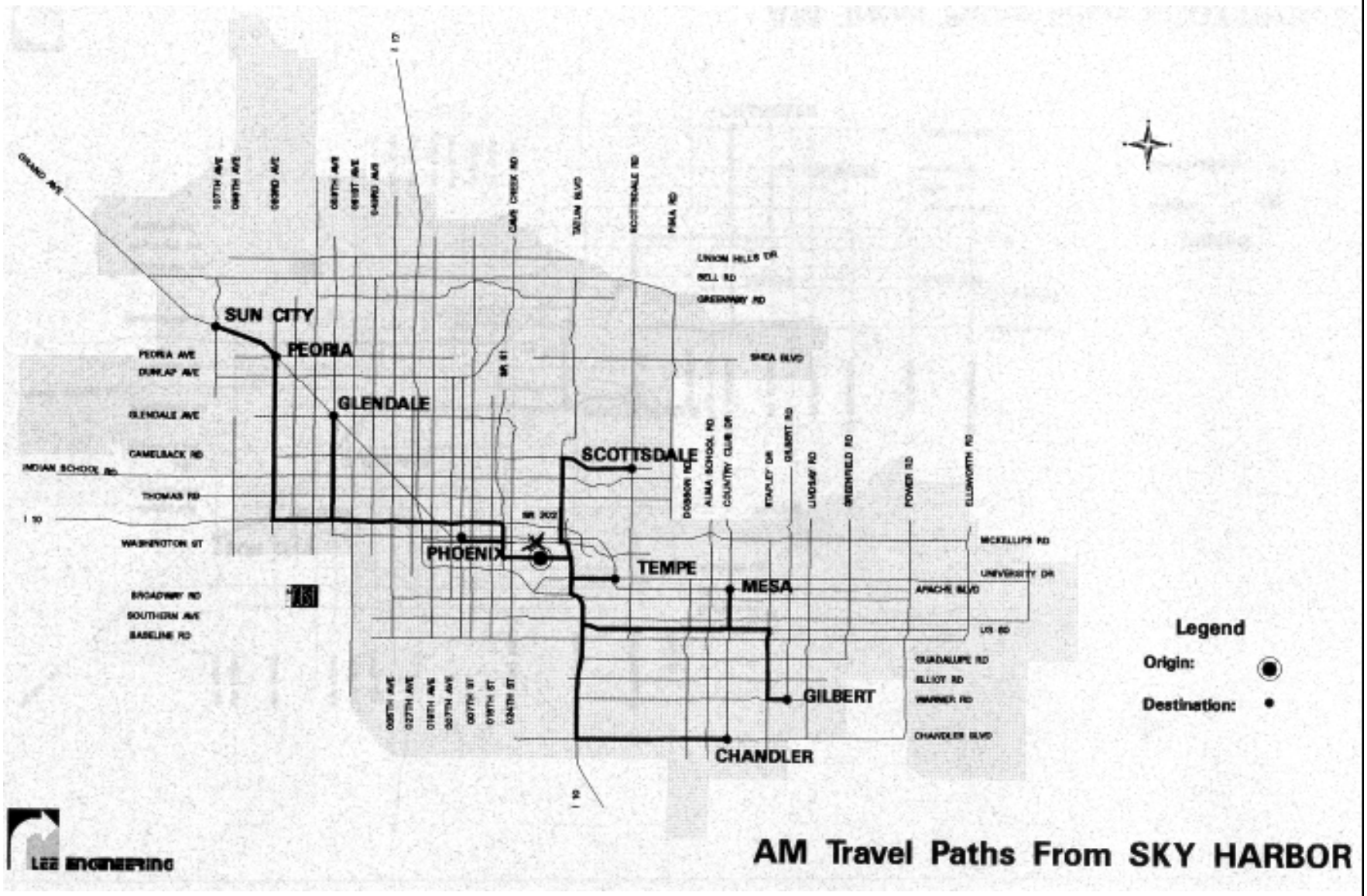
AM Travel Paths From PHOENIX


SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TEMPE
MESA
GILBERT
CHANDLER
Legend
Origin:
Destination:
LEE ENGINEERING
AM Travel Paths From SCOTTSDALE



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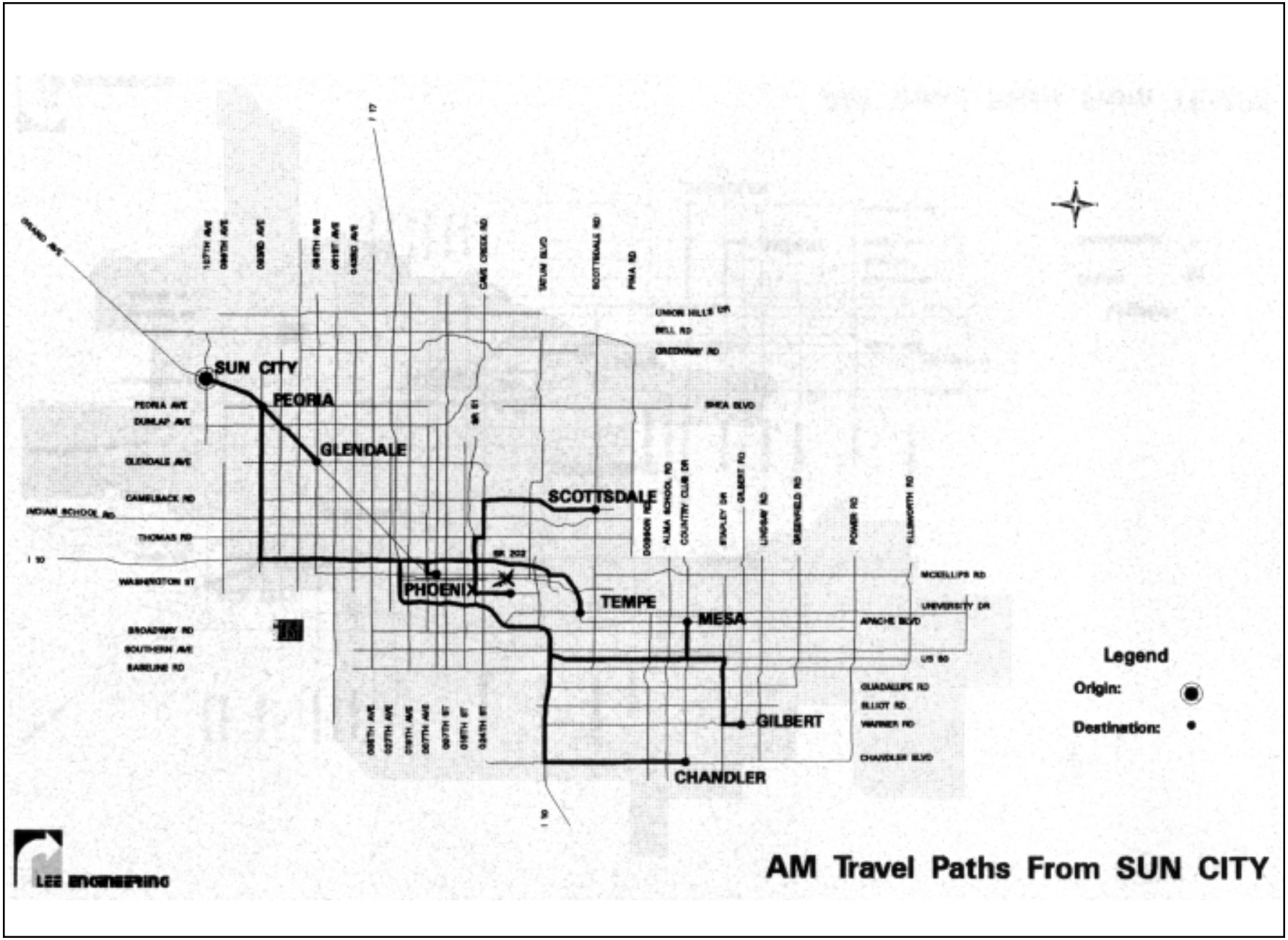
AM Travel Paths From SKY HARBOR



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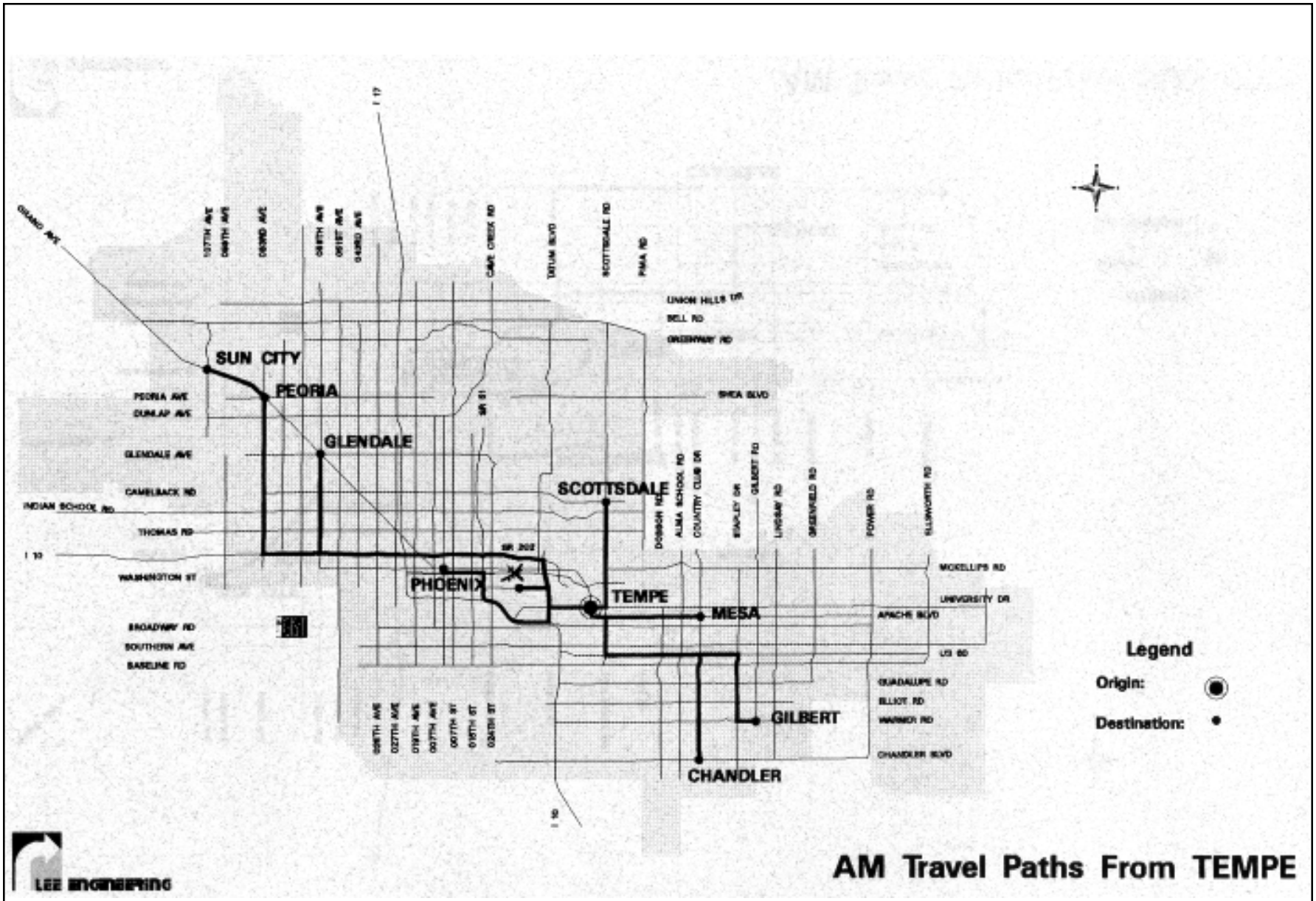
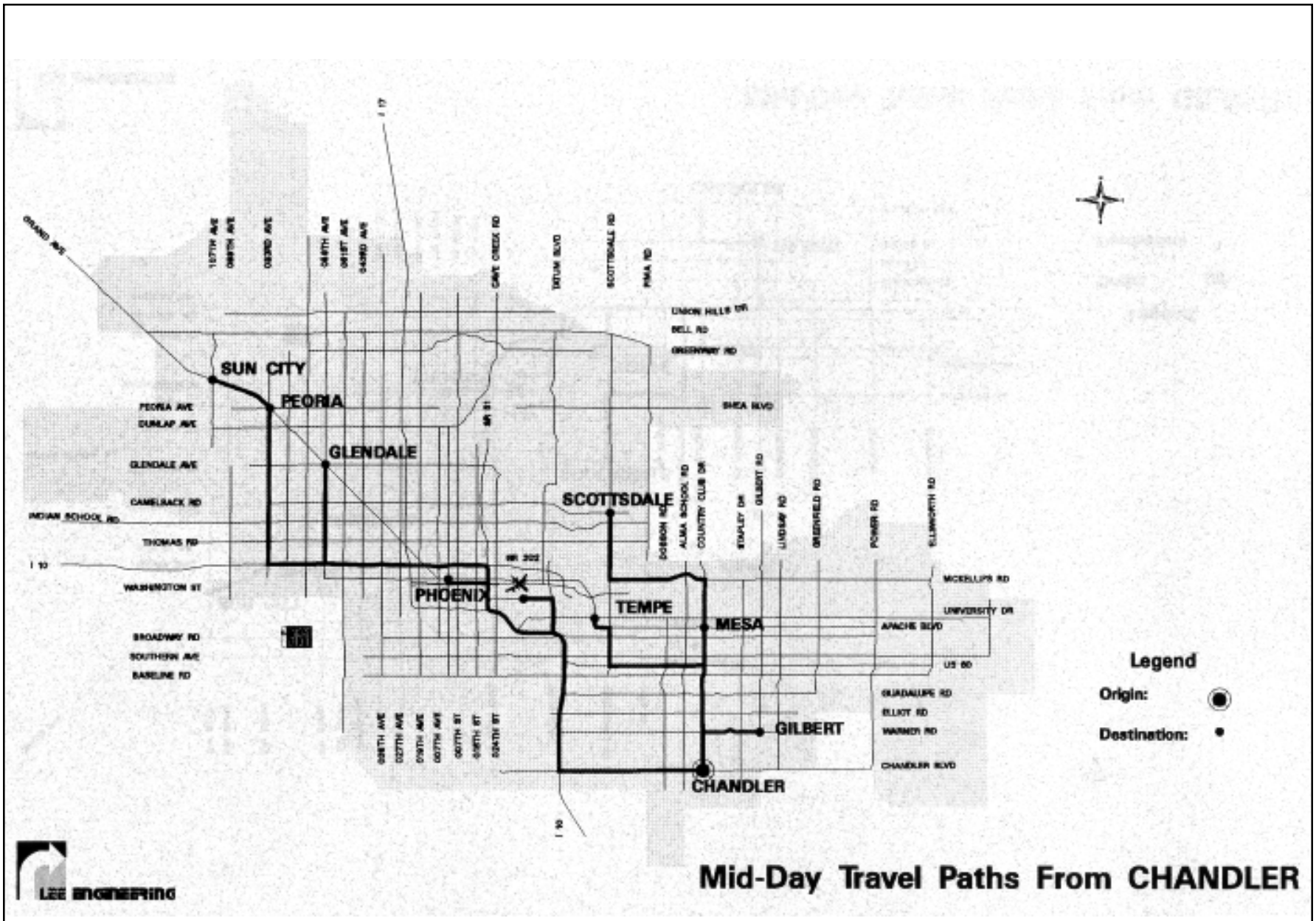
AM Travel Paths From SUN CITY


SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TEMPE
MESA
GILBERT
CHANDLER
Legend
Origin:
Destination:
LEE ENGINEERING
AM Travel Paths From TEMPE



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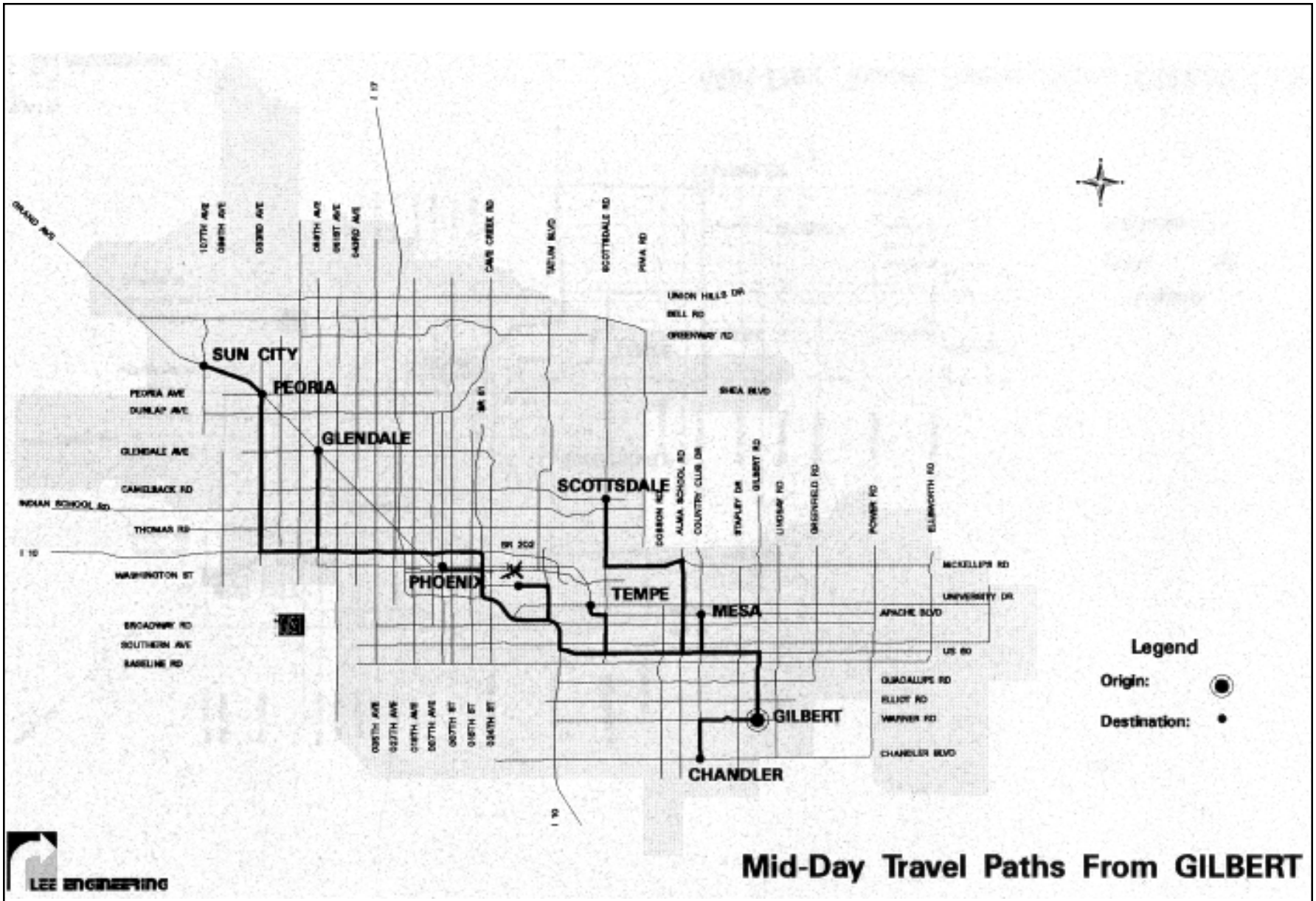
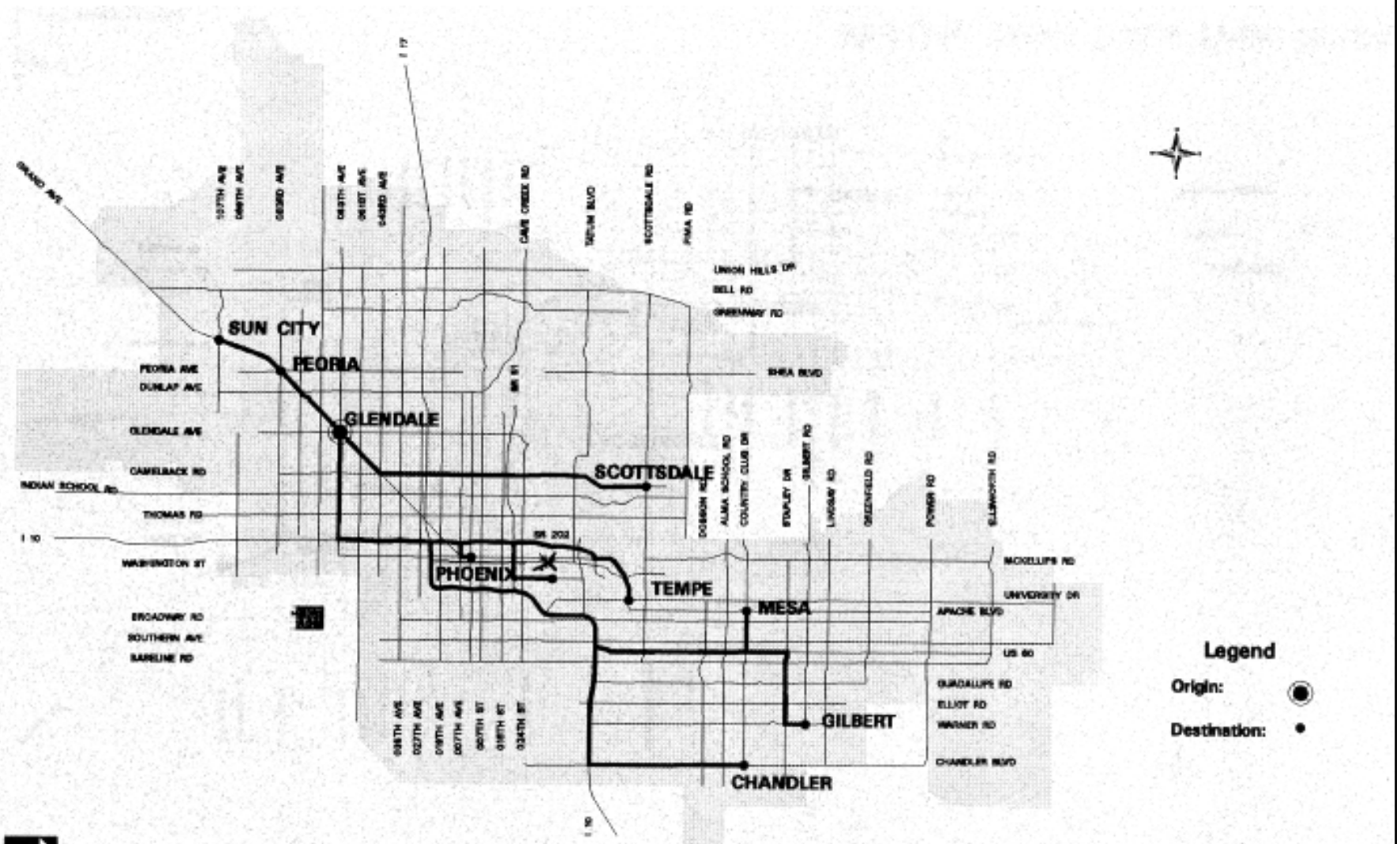
Mid-Day Travel Paths From CHANDLER


SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TEMPE
MESA
GILBERT
CHANDLER
Legend
Origin:
Destination:
LEE ENGINEERING
Mid-Day Travel Paths From GILBERT



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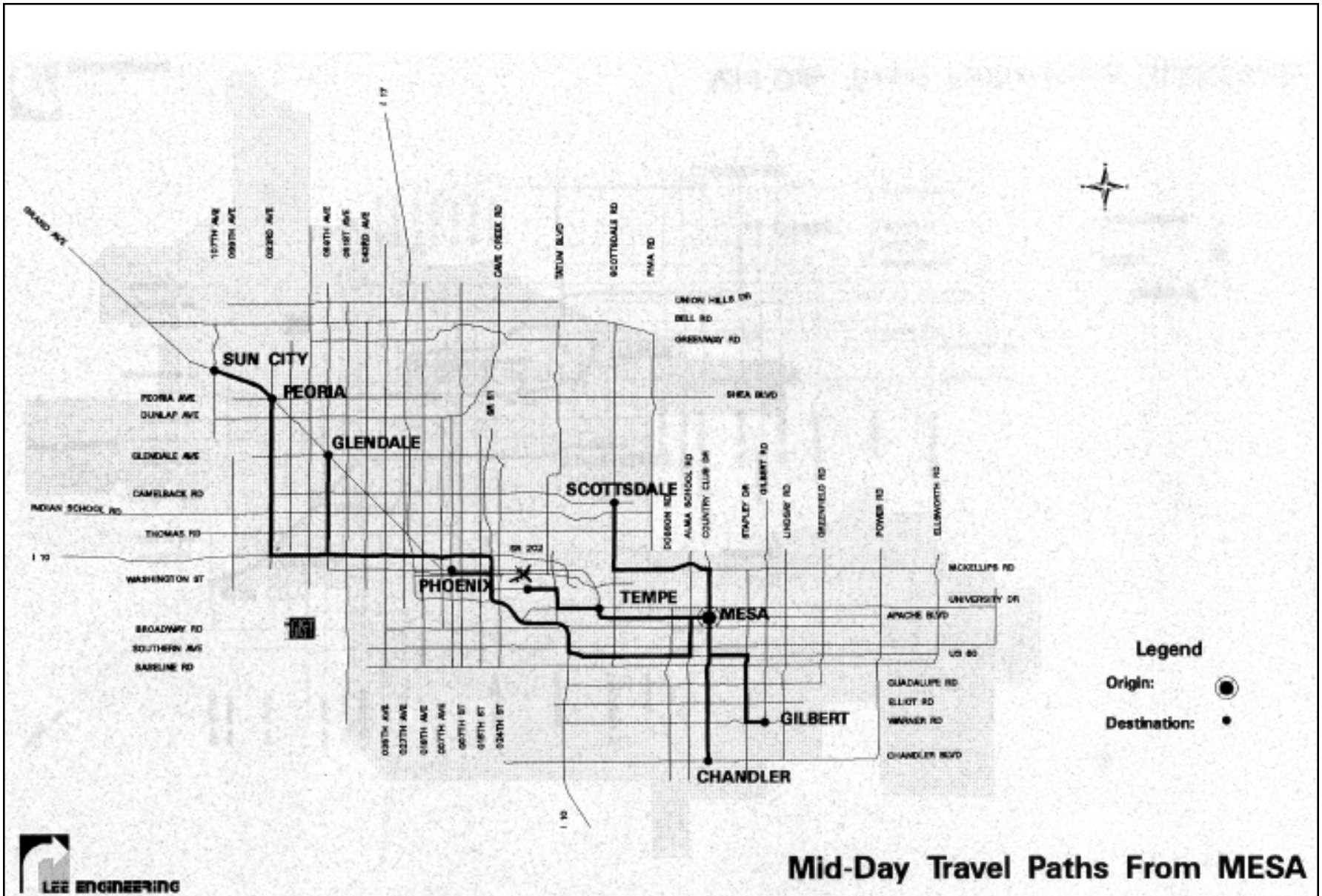
Mid-Day Travel Paths From GLENDALE



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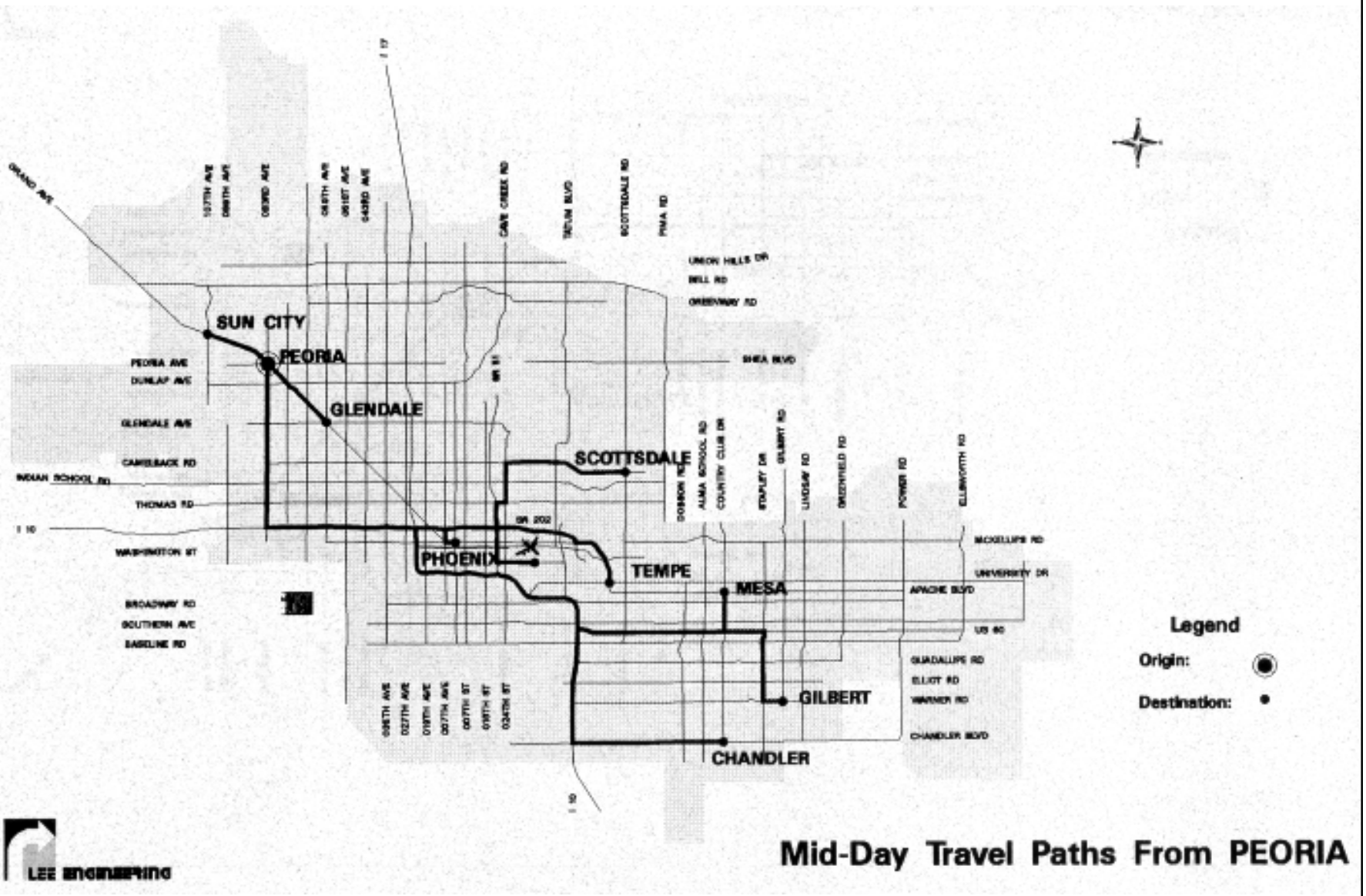
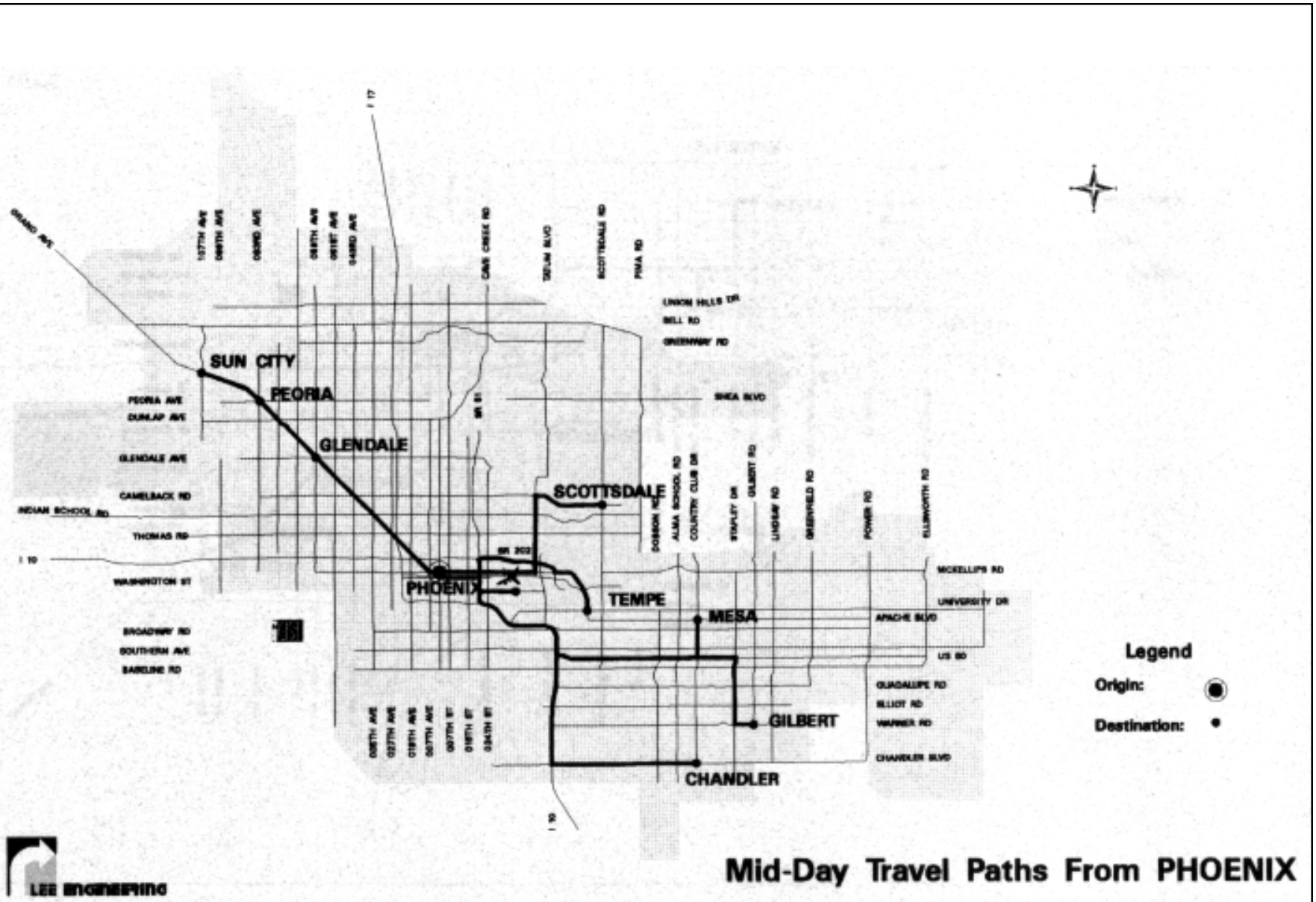
Mid-Day Travel Paths From MESA



LEE ENGINEERING

Mid-Day Travel Paths From PEORIA



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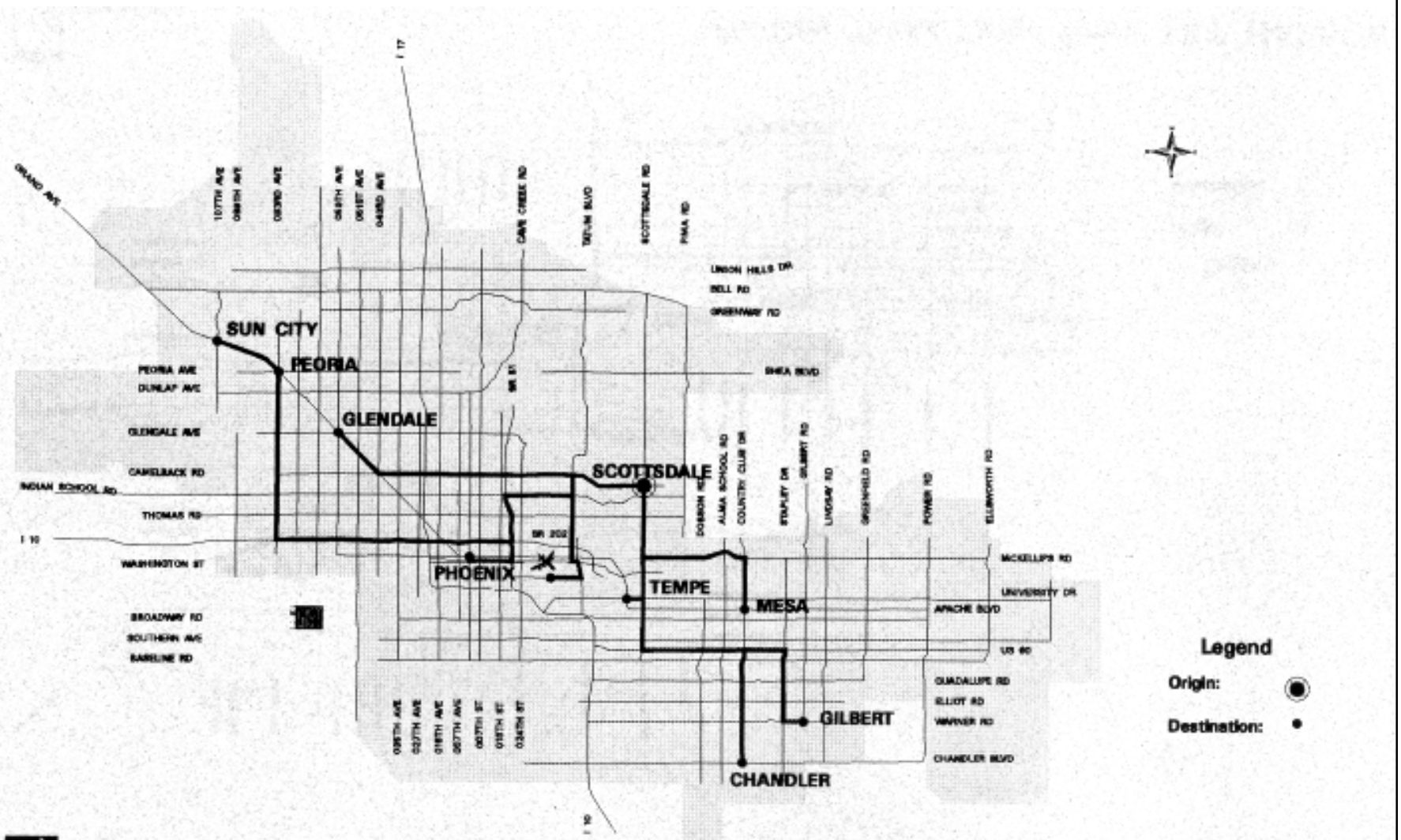
Mid-Day Travel Paths From PHOENIX



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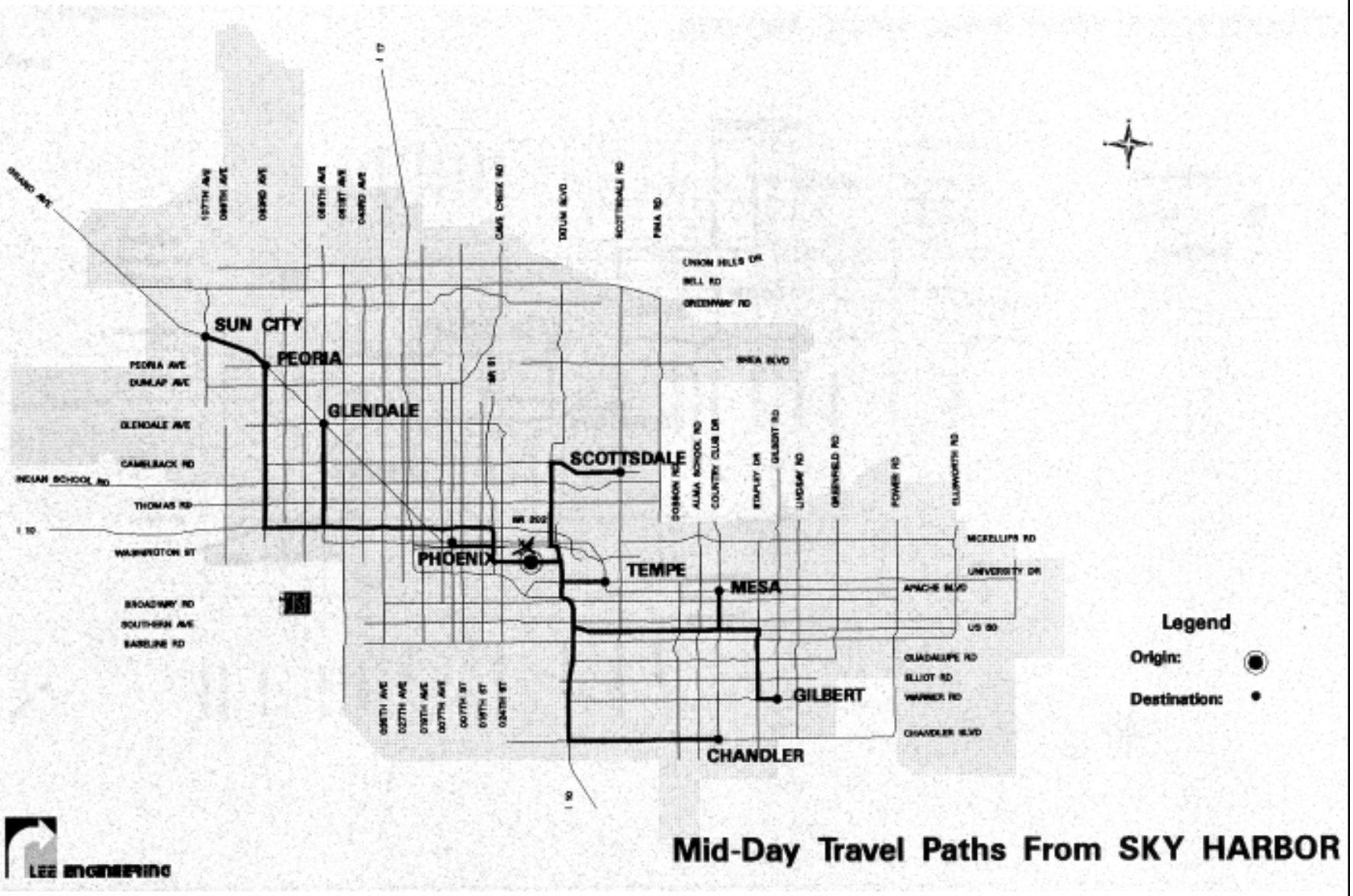
Mid-Day Travel Paths From SCOTTSDALE



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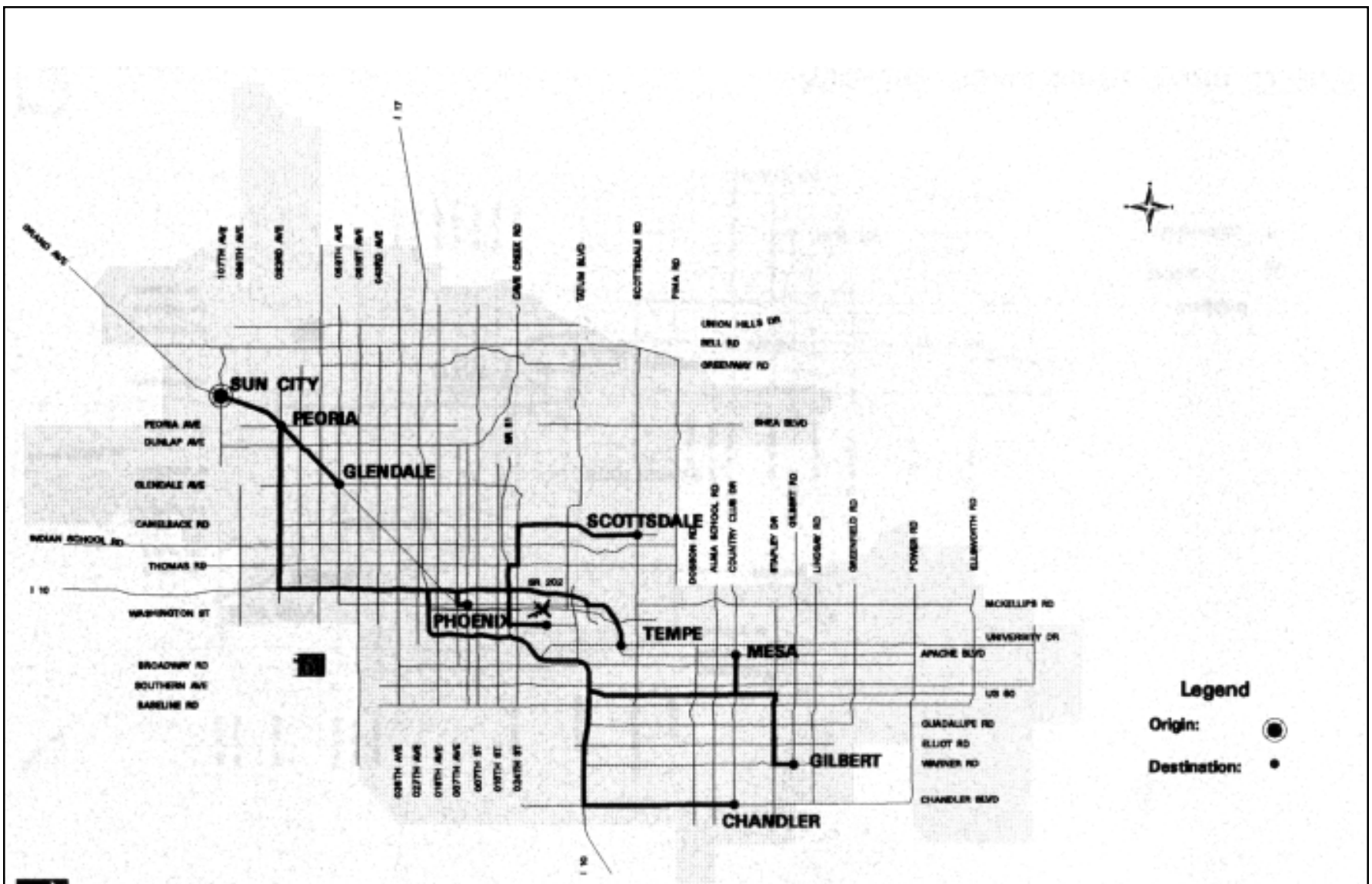
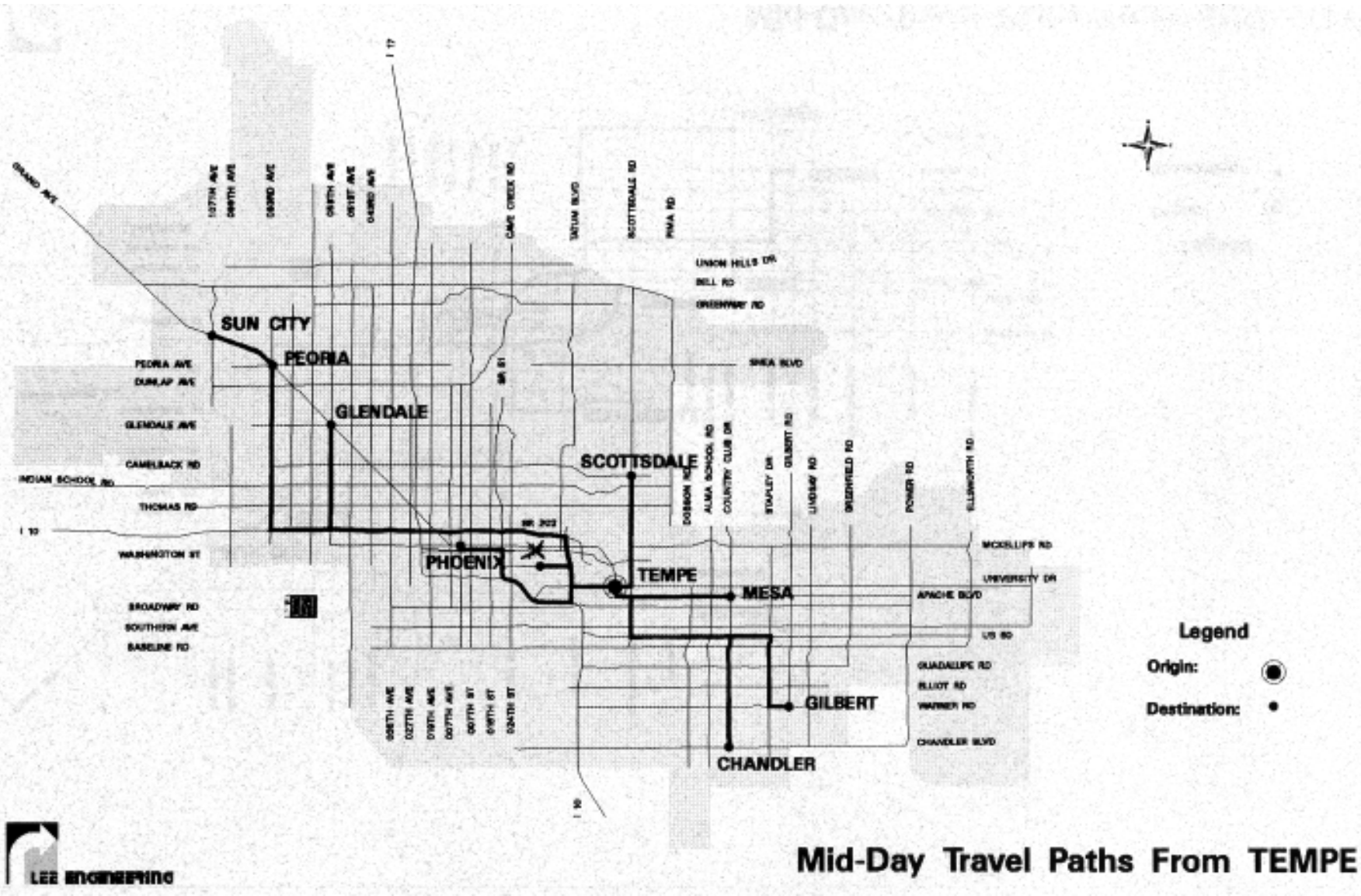
Mid-Day Travel Paths From SKY HARBOR



Mid-Day Travel Paths From SUN CITY



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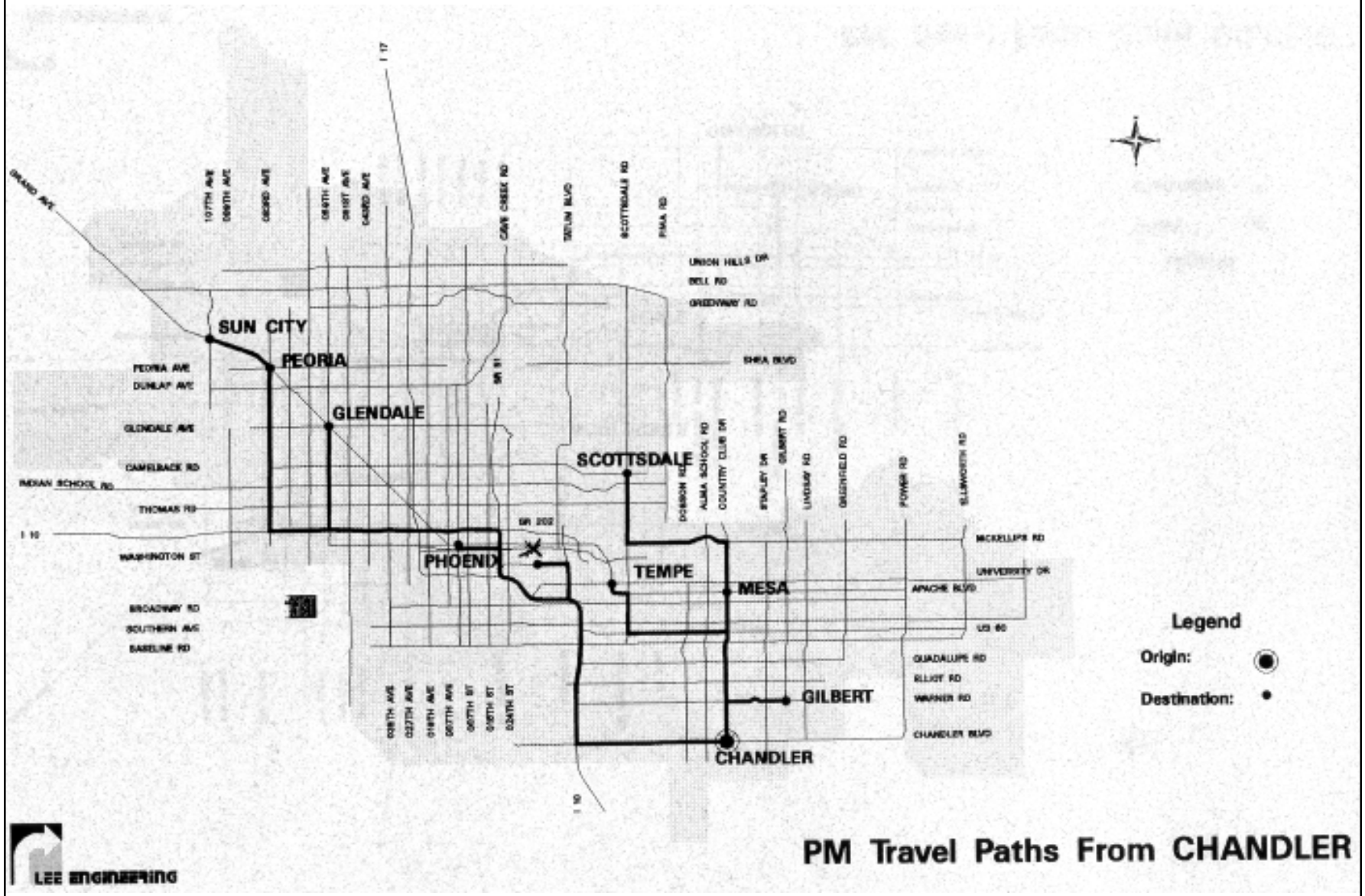
Mid-Day Travel Paths From TEMPE



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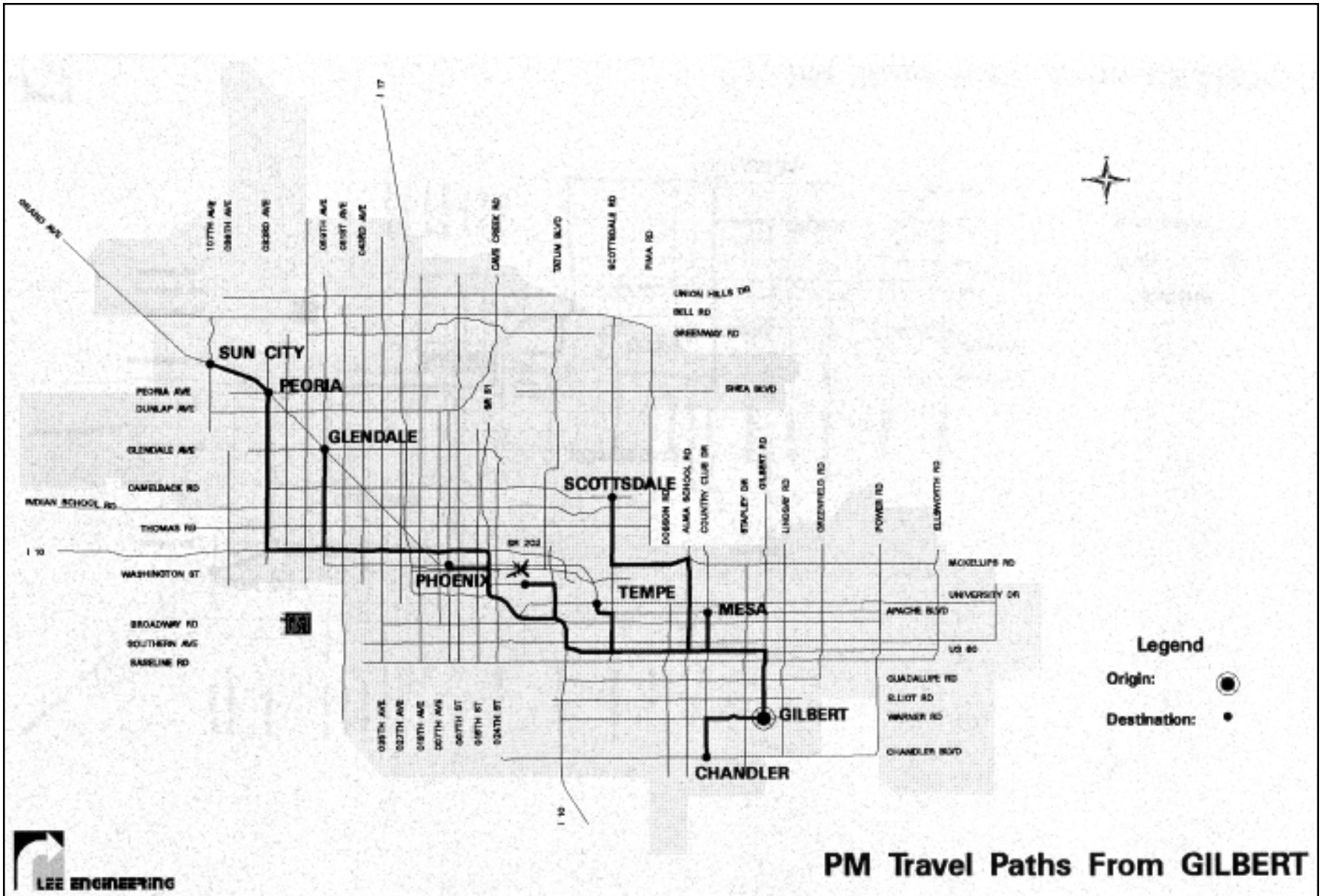
PM Travel Paths From CHANDLER



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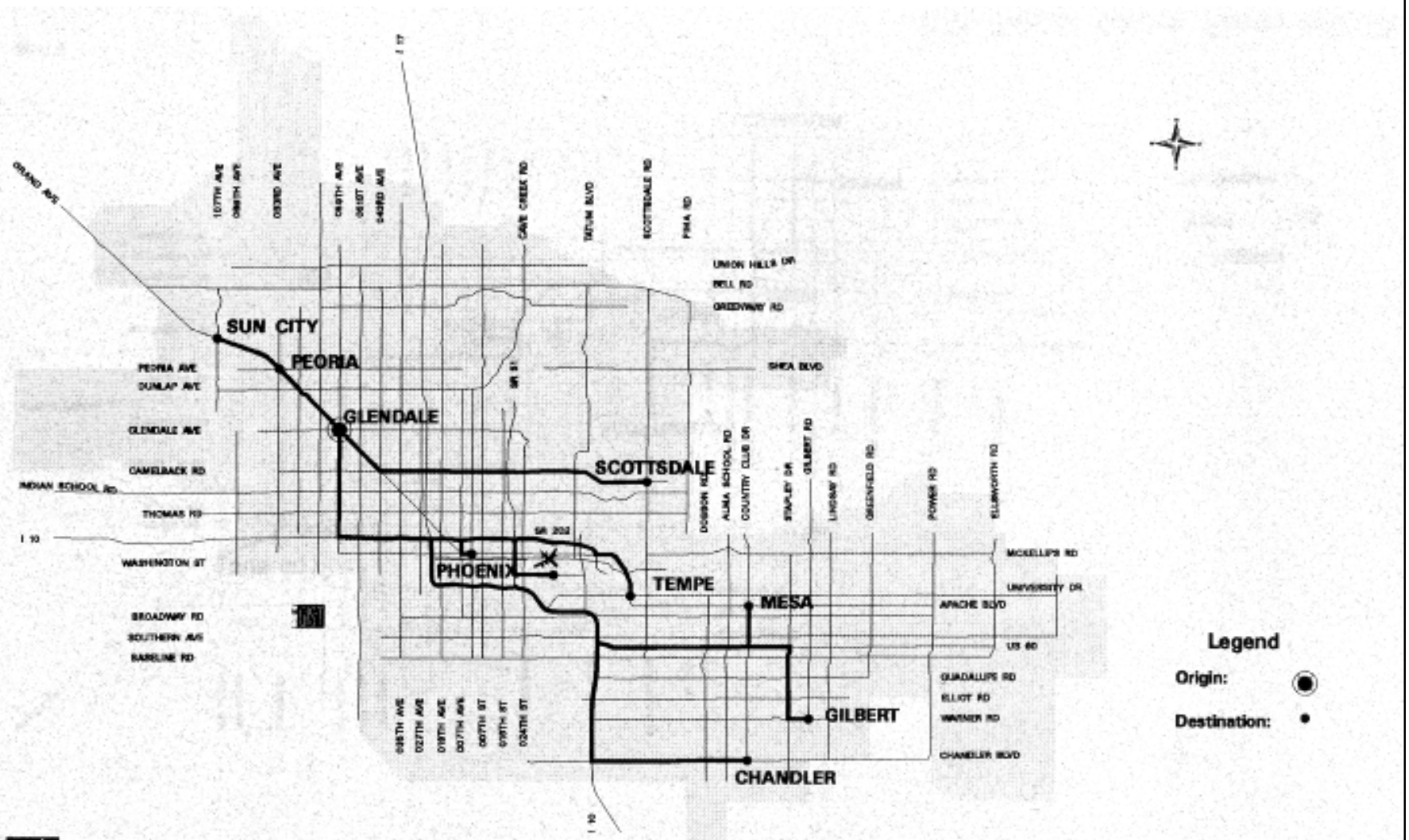
PM Travel Paths From GILBERT



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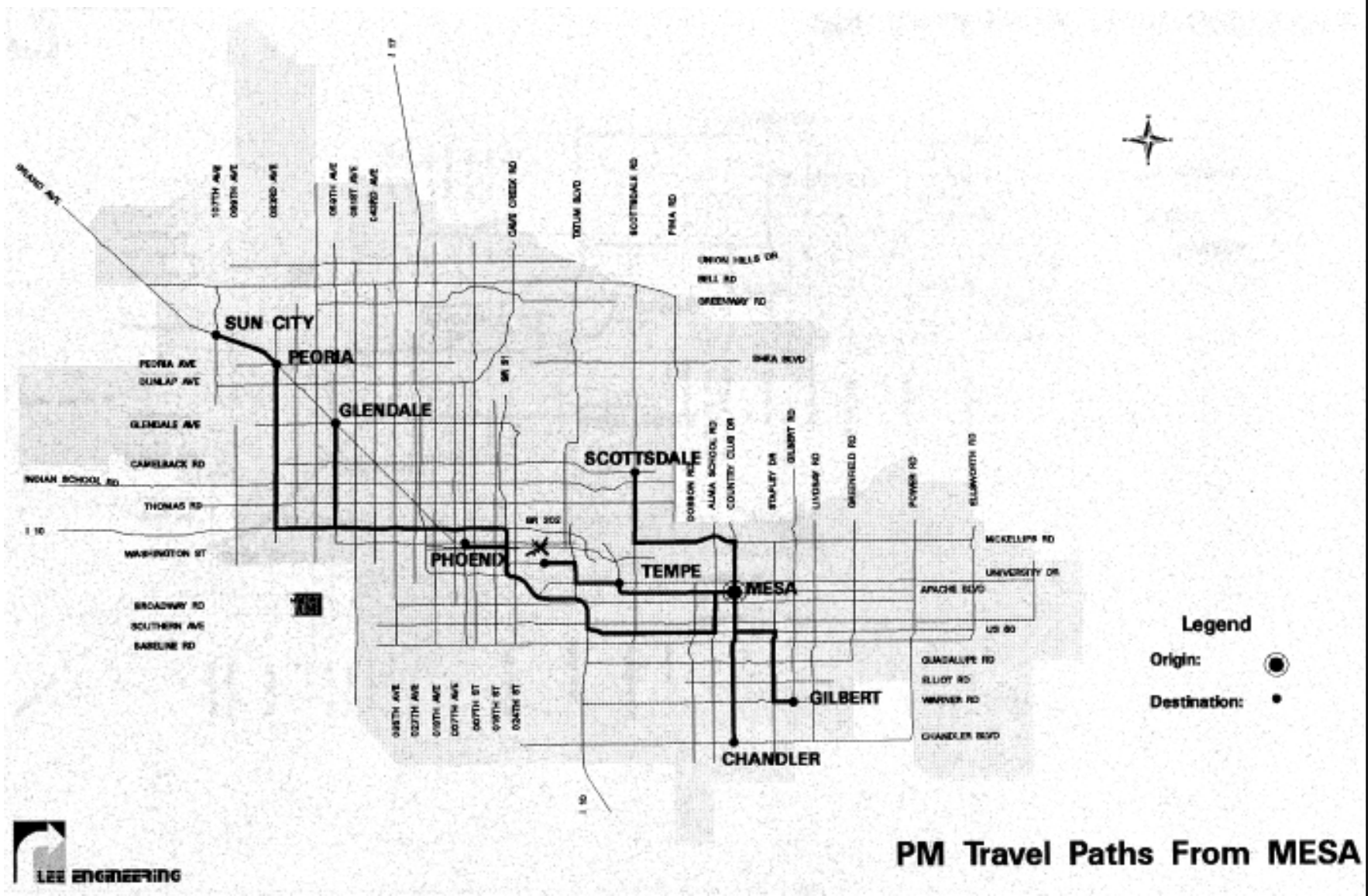
PM Travel Paths From GLENDALE



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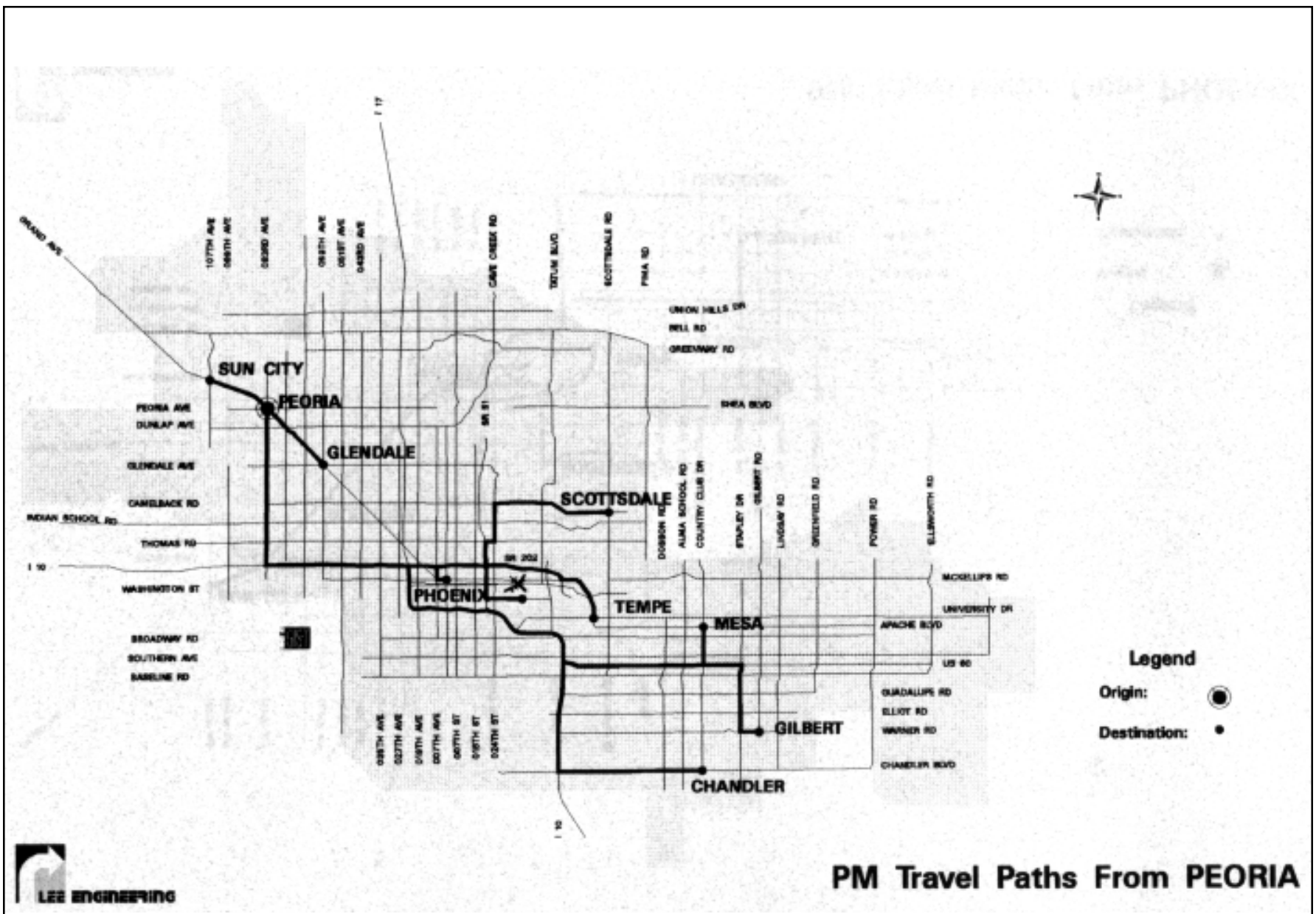
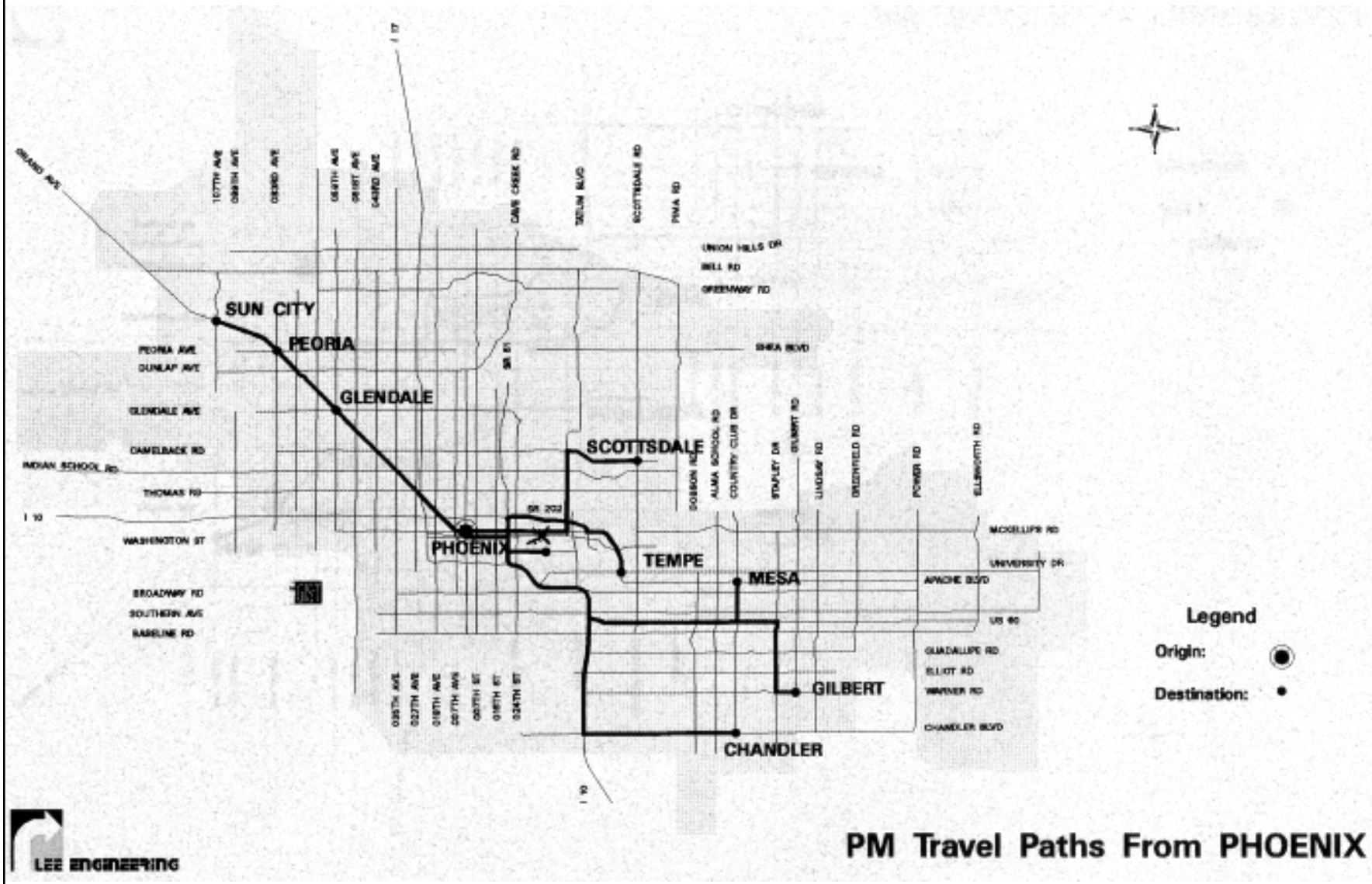
PM Travel Paths From MESA


SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TEMPE
MESA
GILBERT
CHANDLER
Legend
Origin:
Destination:
LEE ENGINEERING
PM Travel Paths From PEORIA



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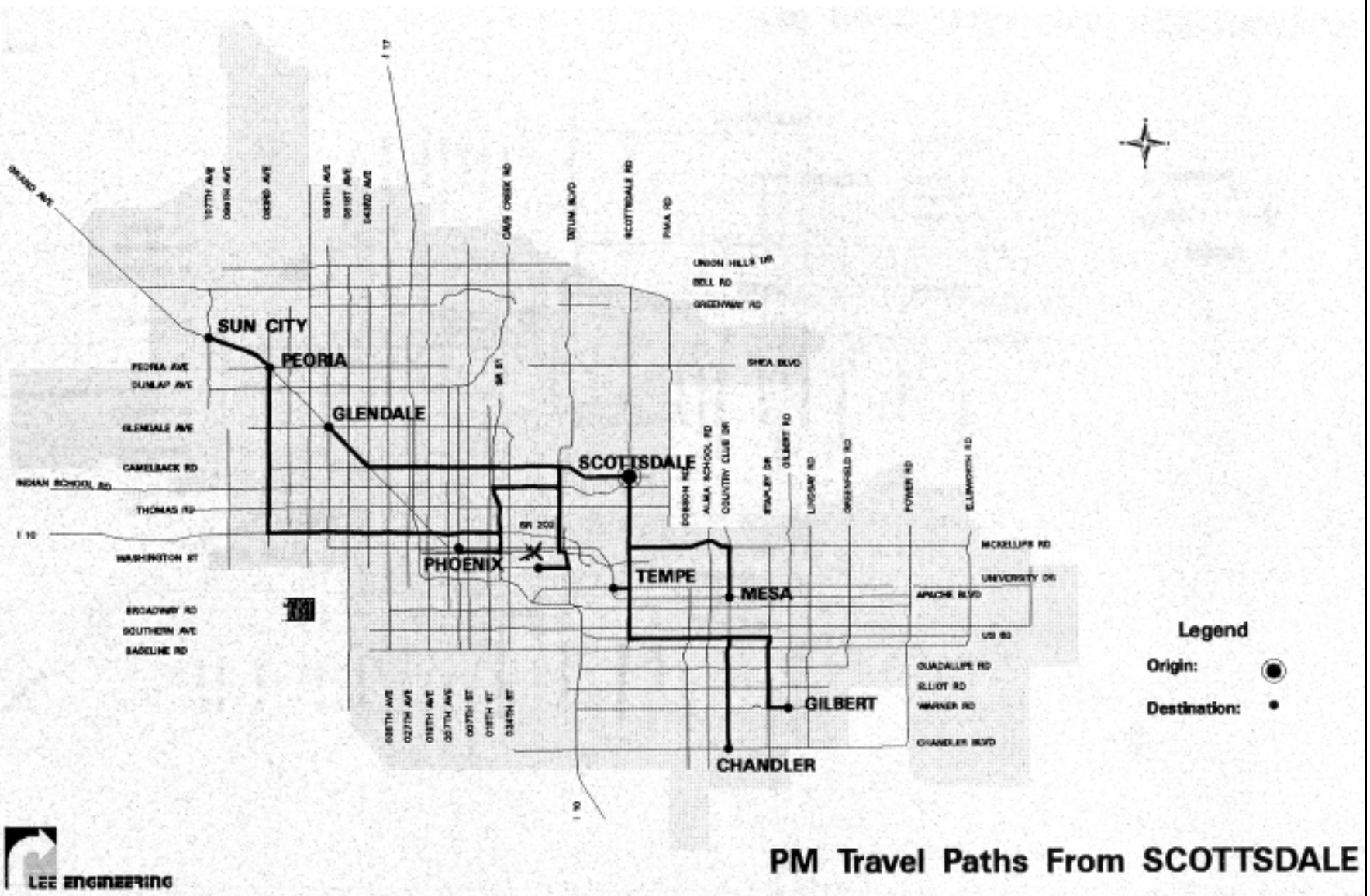
PM Travel Paths From PHOENIX



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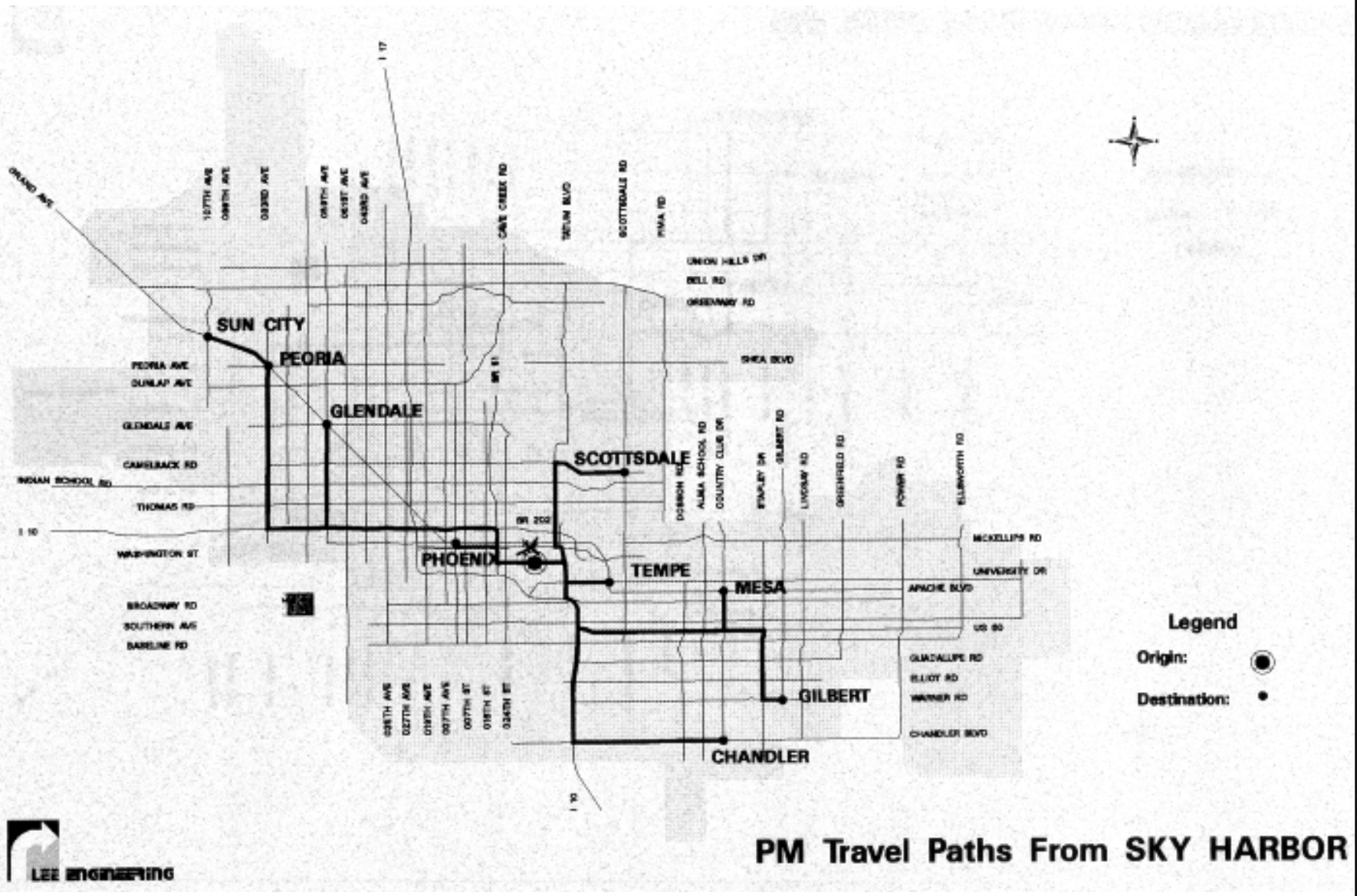
PM Travel Paths From SCOTTSDALE



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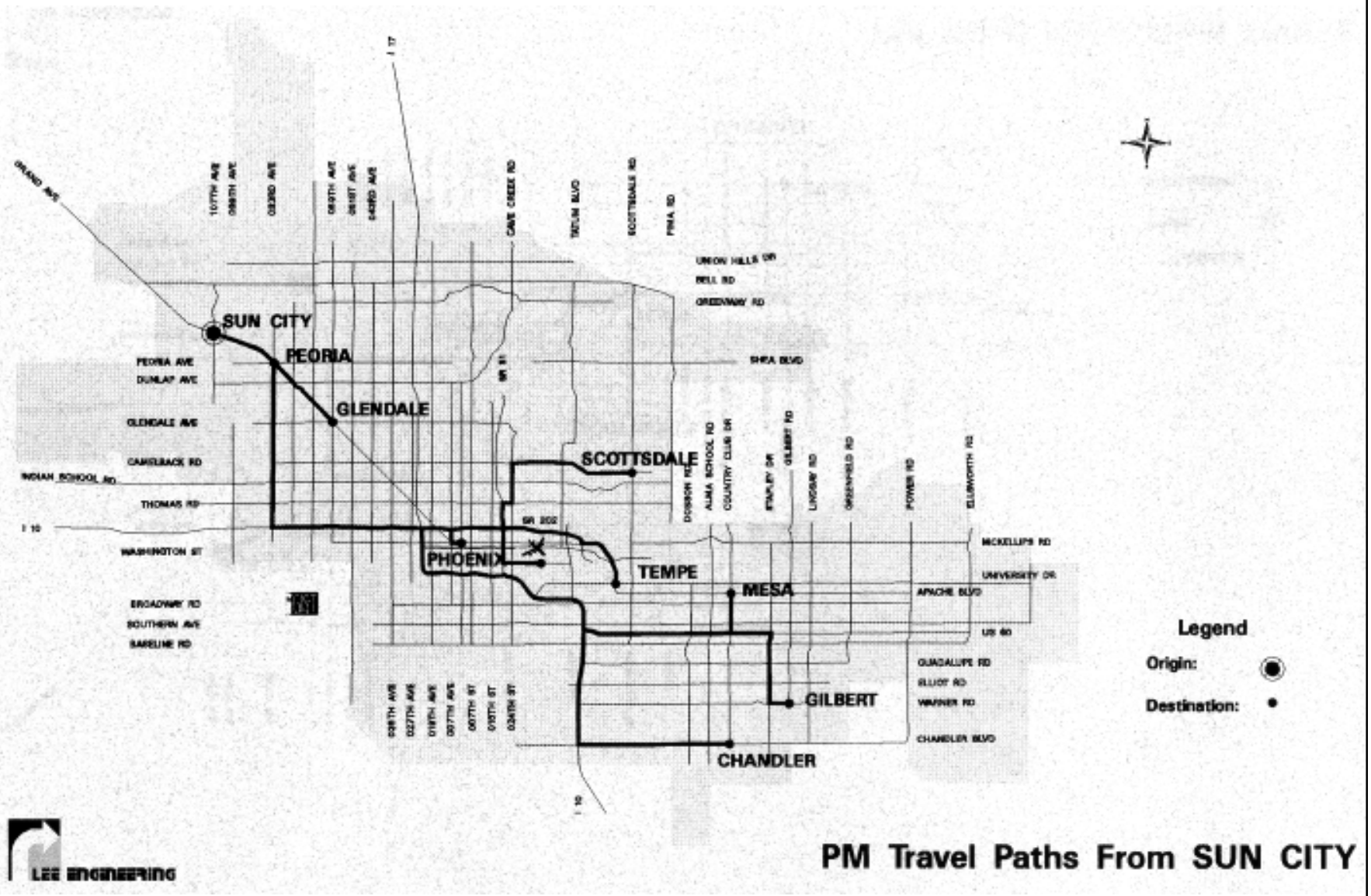
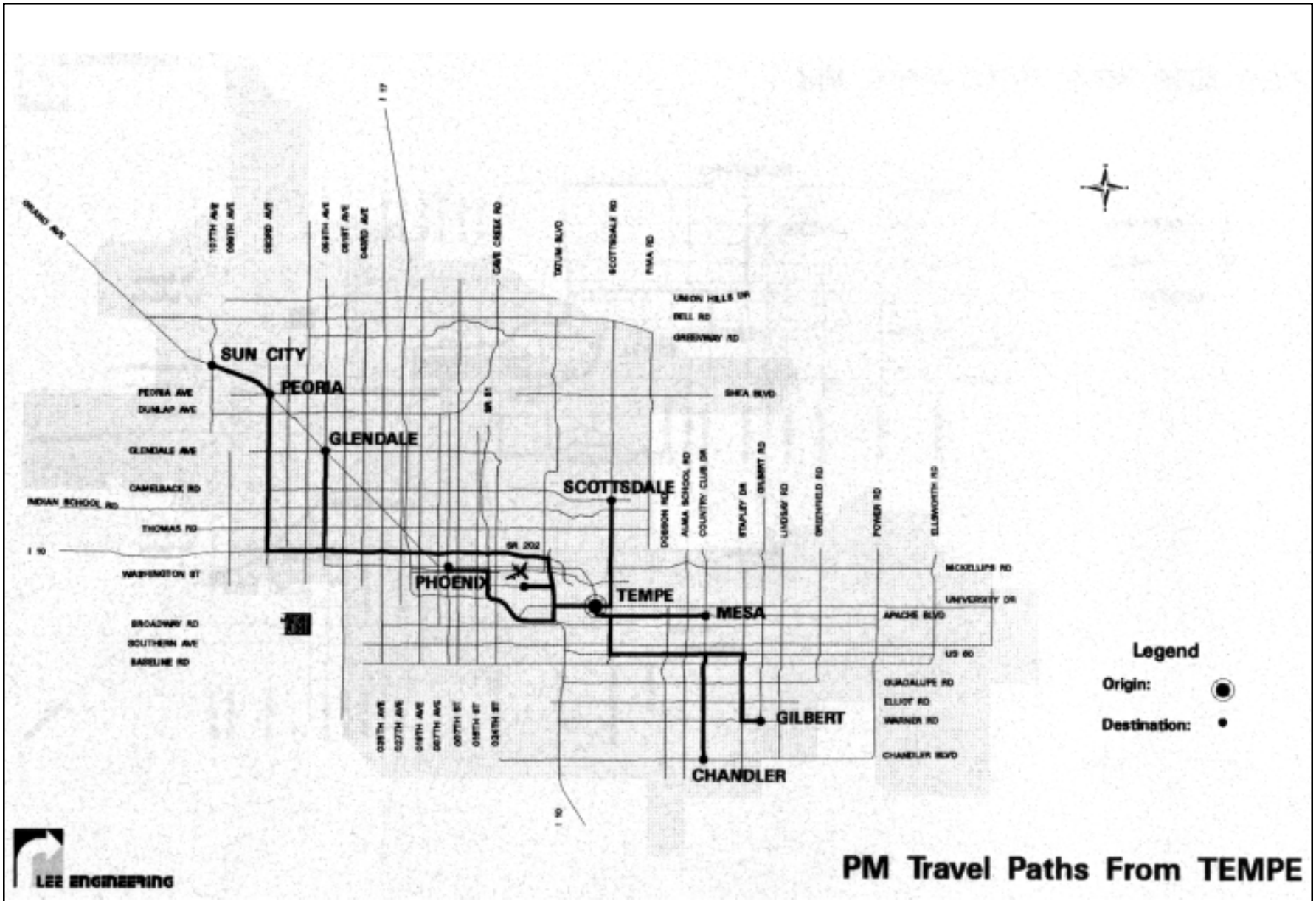
PM Travel Paths From SKY HARBOR


SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TEMPE
MESA
GILBERT
CHANDLER
Legend
Origin:
Destination:
LEE ENGINEERING
PM Travel Paths From SUN CITY



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PM Travel Paths From TEMPE